Bindery

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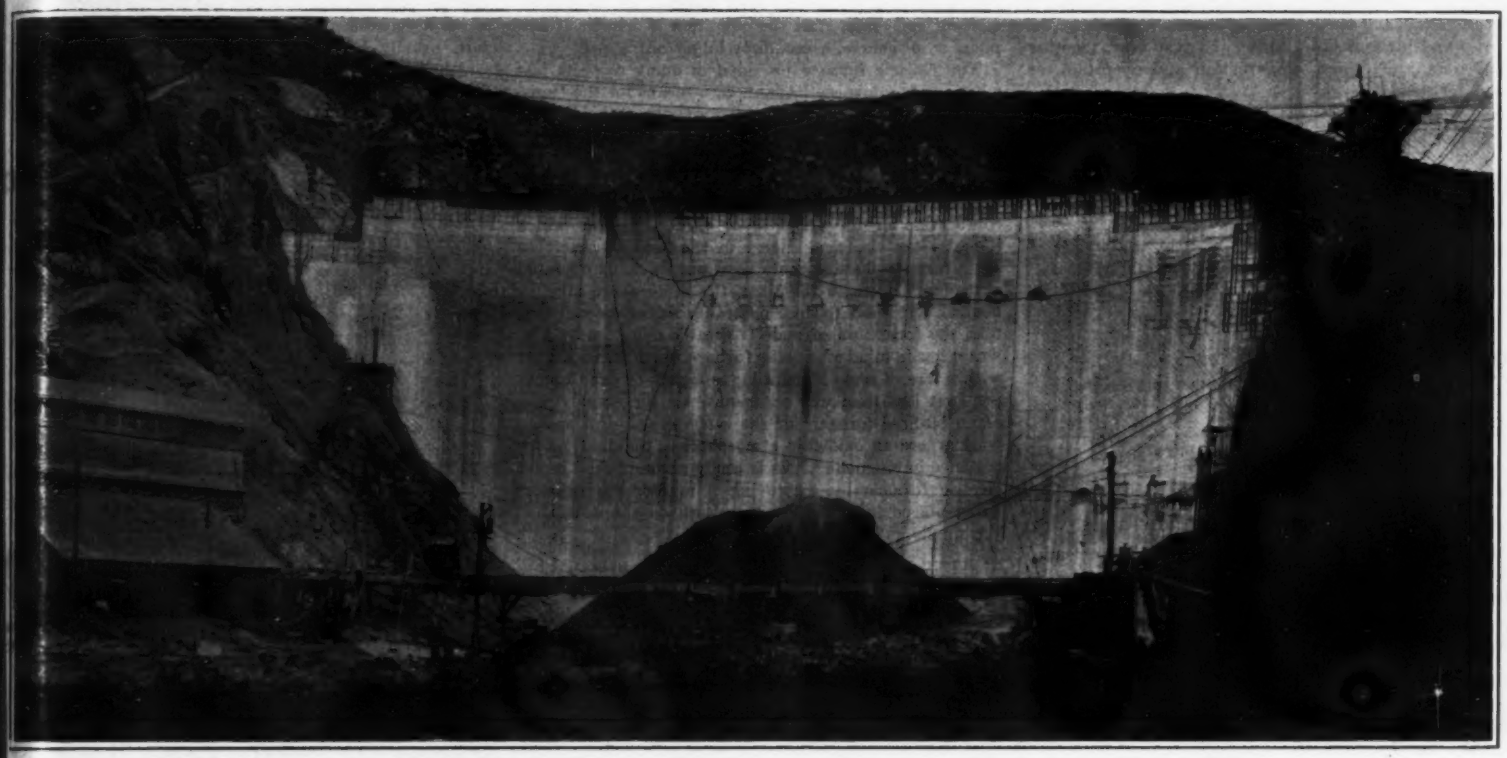


Part of the Arrow Rock Dam, seen from down-stream side. A sharp bend of the river bank conceals the right-hand end.

The Arrow Rock Irrigation Dam. Up-stream face, showing tunnel for the river during construction, also gates that regulate flow from the dam. This dam is 351 feet high and 1,060 feet long at the top.

THE ARROW ROCK DAM.—[See page 340.]

Electric Furnaces for Heating Steel—I*

Facts and Figures Relating to New and Valuable Methods

By Alcan Hirsch

THE field of usefulness of the electric furnace for metallurgical purposes is so extensive that it is deemed advisable to limit the scope of this paper to a discussion of electric furnaces used for heating steel for the various kinds of heat treatment, forging and enameling. A broad view of the development of electric furnaces by the writer and his associates during the past year, together with details of design, construction and operation, as determined by them are presented herein. The essential data only are given as it is believed that extensive details are likely to lead to confusion.

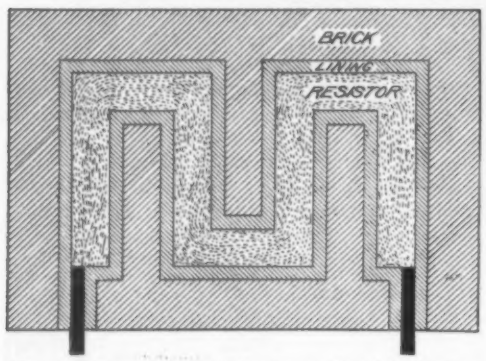


Fig. 1.—Serpentine resistor for moderately large furnaces.

Prior to 1913 attempts were made to put forth furnaces for metallurgical purposes, but except for the very small furnaces, these cannot be considered as having had commercial success. The facts which form the basis of this paper occurred under the writer's observation and are practically exclusively gathered from his experience of the past year.

By reason of industrial practice and certain other limitations, both fuel and electric furnaces can be divided into two classes:

I—Furnaces operating above 1,800 deg. Fahr. Forge furnaces are the main and most important division of this class.

II—Furnaces operating below 1,800 deg. Fahr. This class comprises furnaces for practically all heat treating as well as enameling. Although furnaces operating at the lower temperature will be considered first it must be borne in mind that the greater part of the principle and theory underlying the construction and operation of moderate and low temperature furnaces also applies to the higher temperature furnaces.

TRANSFERENCE OF HEAT FROM HEATING MEDIUM TO METAL.

The metal resting on the hearth of the furnace receives its heat in several different ways: (1) From the brickwork in the furnace in contact with the metal; (2) by conduction from the products of combustion; (3) by radiation from the hot walls, roof and incandescent particles in the burning gases. Generally speaking, in the fuel-fired furnaces, each of these paths delivers heat of the same order of magnitude, but usually the amount of heat passing by means of brick and metal in contact is less than that by any other path. If only a small portion of the heat passes into the metal by direct contact with the brick, the rate of heating in all except thin pieces is quite slow. More frequently than is generally supposed this path of heat transfer is the determining factor in the rate of heating. An excellent example of this kind was brought to the writer's attention where die blocks were being heated. In this instance the furnace was heated to a sufficiently high temperature so that the heat content of the brick work was sufficient to supply the necessary heat to raise the blocks to the desired temperature. Sometimes the fuel was allowed to run sparingly throughout the operation, while at other times it was shut off entirely after the block was placed in the furnace.

ATMOSPHERE IN FURNACES.

The atmosphere of fuel-fired furnaces is exceedingly uncertain. Slight variations in conditions have been found to make marked variations in results, and as the atmosphere is capable of a great many variations, it is, therefore, quite difficult to maintain it at a definite composition. With oxidizing conditions the formation of scale occurs, while in a reducing atmosphere local carburization results from the sooty flames. In the production of high-grade steel the condition of hearth atmosphere is, of course, exceedingly important.

The electric furnace provided in many respects just what the fuel furnace lacks; i. e., a means for the transference of heat in a very effective manner, and a furnace atmosphere which is not only of a very desirable composition, but which is absolutely dependable. This atmosphere is usually of a slightly reducing nature, caused by the presence of carbon monoxide, due to the combustion of the graphite or carbon resistor which liberates the electrical energy in the form of heat. In some furnaces having more than one door, or operated with doors open all the time, the atmosphere may be neutral. It is due to these neutral or reducing conditions that the formation of scale is greatly minimized. The writer has in mind an electric furnace which was operated with a loss of scale amounting to eighty or even ninety per cent less than was occasioned by the employment of an oil-fired furnace for the same work. For special work where an oxidizing atmosphere is required, as for instance in enameling, this is easily accomplished in the electric furnace by employing a muffle, the resistors being placed in any desired position on the outside of the muffle.

ELECTRIC FURNACES FOR TEMPERATURES BELOW 1,800 DEG. FAHR.

The industrial electric furnaces of this type which have obtained commercial success have employed a resistance wire or ribbon as the heating element. The limitations of these wire or ribbon-wound furnaces are quite marked, generally speaking, as regards both temperature and capacity. As will be shown subsequently, temperature and capacity of a furnace are closely interrelated. This interrelation of temperature and capacity, however, is not of so much consequence in the small furnaces where the combined wall and door losses are considerably in excess of the heat actually utilized in raising the metal to the desired temperature. The capacity of the metallic resistor is at most but a very few kilowatts. Furnaces with a larger capacity would be quite out of the question because of the cost of the resistance element due to the large amount of wire required and the expense of winding. The furnaces are, therefore, limited to productions of small size and also to rather moderate temperatures as danger of burning out due to overheating is quite imminent. For small furnaces, however, this type has proven quite satisfactory in a large quantity of work of an experimental nature.

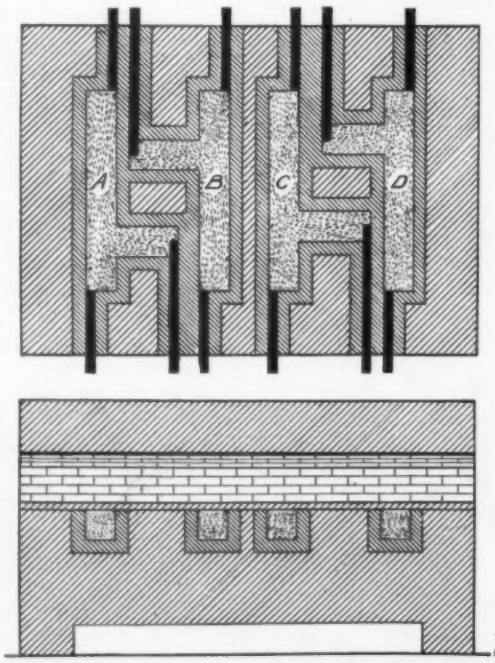


Fig. 3.—Furnace capable of regulation without a transformer—adapted for 10 square feet or over hearth area.

Furnaces employing non-metallic resistors comprise two types: (1) Those where the metal to be heated is in contact with the resistor; (2) those where the metal to be heated is out of contact with the resistor.

Furnaces of the first class have had but one commercial example, and that has had varying success. This is the bath furnace[1] which employs a conducting bath of salt, usually barium chloride and potassium chloride, which is used by the passage of the current through it. The steel to be heated is immersed in this bath of fused salts. This type of furnace appears to the writer to be too limited for extensive industrial application, and, therefore, will be given only this brief mention.

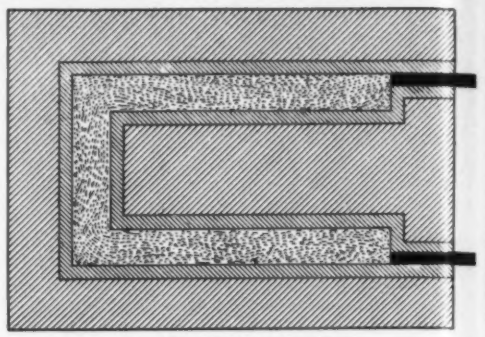


Fig. 2.—U-shaped resistor.

Furnaces of the second class, those employing non-metallic resistors, where the metal is heated out of contact with the resistor, hold forth much promise for future development, in the opinion of the writer. Recent experience with their operation has demonstrated their suitability to many kinds of work. In general, furnaces of this class appear to the casual observer, very similar to the fuel-fired furnaces, save for the fact that instead of equipment for burning fuel, electrical equipment will be noted. The electric current is brought to the furnace by suitable cables which are connected to electrodes projecting from the furnace. These electrodes run through the furnace wall and carry the current to the resistor which liberates, in the form of heat, the electrical energy put into the furnace. The resistor is a refractory conducting material, such as graphite, usually in granular form, and has a cross-section of 30 to 100 square inches according to the current desired. The resistors are usually placed beneath the hearth, the heat from them being communicated through the hearth to the metal.

For the design of a heat-treating furnace to operate at a hearth temperature of 1,800 deg. Fahr., or less, the following data have been found necessary for the preliminary calculation of the major points of design:

1—The hearth dimensions.

2—The production of metal per unit of time.

3—The maximum amount of metal on the hearth at any time.

4—The desired temperature.

5—Time for charging and discharging.

The first step in the design is the approximation of the location of the resistor, but this depends somewhat on the physical characteristics of the material employed for the resistor. Resistors placed in the furnace in granular or similar form have been much more extensively employed in the larger furnace than any other kind. Rods of graphite and also of other materials, metalloids as well as the characteristic non-metallic materials, have been tried for use as resistors. Although some of these will undoubtedly find commercial fields, as yet nothing has proven satisfactory in this direction. Attention, therefore, will be confined to granular or similar materials, of which granular graphite has served most satisfactorily.

For the usual type of electric furnace work of this class the location of the resistor is logically in the base of the hearth. For a small proportion of the furnaces, however, resistors can be placed elsewhere advisedly. These positions are along the side of the hearth and possibly even along the top. Furnaces requiring resistors in these latter locations are those taking piles of sheet metal or pots of materials, and the like. However, with one layer of pieces, which rests directly on the hearth, the location of the resistor had best be exclusively in the base. The reasons for this are: (1) heat has a tendency to ascend rather than to descend; (2) contact between hot brick and the metal to be heated facilitates heating; (3) the design is facilitated as will be subsequently developed. When the resistors are placed in the base of the furnace

*Author's abstract of report on research carried out under a Carnegie Fellowship granted by the Iron and Steel Institute of Great Britain. The complete report of this work was presented at the Annual Meeting of the Institute, May 7th, 1914. This abstract is reprinted from the *Journal of Industrial and Engineering Chemistry*.

[1]An article on this furnace by L. M. Cohn will be found in the *Electrotech. Zeit.*, August 2nd, 1906.

they are put in troughs of suitable refractory material and usually, but not always, covered partly or completely with brick or tile, which forms the hearth.

The shape of the resistors can be exceedingly varied. They may be straight, U-, S-, T-, or Y-shaped. They may be electrically connected in series or parallel, or some in series and others in parallel. They may be permanently electrically connected, or they may be capable of various electrical arrangements by switching.

PERMANENTLY ELECTRICALLY CONNECTED RESISTORS.

Furnaces with these resistors are constructed so that they must be operated in one manner, at all times from the point of view of electrical arrangement. In practically all furnaces of this class either a serpentine or U-shaped resistor may be employed, but two or more straight resistors connected either in series or in parallel may be used instead. Fig. 1 shows the serpentine resistor which has been employed in moderately large furnaces only, it being impossible to adapt this type to the smaller furnaces. The U-shaped resistor shown in Fig. 2 has been employed in furnaces of any size but has some limitations which will be considered later.

There are several ways to determine the electrical load for a given furnace, but they all resolve themselves into one method, which is the only one deemed sufficiently practical to be given consideration in this paper. Only furnaces of 200 kilowatts capacity or less will be considered and it may be said that furnaces for heat treating larger than this are exceedingly rare. The electrical load is the sum of three factors: (1) the electrical equivalent of the amount of heat necessary to raise the metal to the required temperature; (2) the electrical equivalent of the loss of heat through the walls; (3) the electrical equivalent of the loss of heat through the door, in consideration of the fact that this is alternately opened and closed. Since the power factors of furnaces of this size are from 97 to 99 per cent, they can be neglected in the calculation of the necessary wattage. From the data in Table I the watts necessary to operate any particular furnace may be approximated quite closely. The door loss shows the watts passing through the door opening if the door is open all the time. If the door is open only half the time, only half the amount given in the table should be taken, and so on in proportion. The wall upon which the wall loss figures are based is 12 inches thick, consisting of 9 inches of silica brick and 3 inches of kieselguhr. By actual practice this has been found to be a convenient standard. As an example of the method of calculation, the electrical load for a particular furnace will be determined. Assume the following data for this illustrative case:

1—Outside dimensions—4 feet × 4 feet × 6 feet long.
2—Production—500 pounds of steel per hour.
3—Temperature—1,760 deg. Fahr.
4—Door—2 square feet, open 40 per cent of the time.

This furnace had a total outside area of 128 square feet. The table shows a wall loss of 0.060 watt per square foot, making a total loss of 7.68 kilowatts for the walls, top and base. The door loss would be 10.0 kilowatts if the door were open all the time, but it being open but 40 per cent of the time, the loss is 4.0 kilowatts. As 0.0881 kilowatt is required to raise 1 pound of steel to 1,700 deg. Fahr. from 60 deg. Fahr. in 1 hour, 500 pounds per hour would require 44.05 kilowatts.

TABLE I.

Temperature of operation.		Kilowatts to raise 1 lb. per hr. from 60° F.	Wall loss (*a*) in k. w. per sq. ft. outside surface.	Door loss (*b*) in k. w. per sq. ft.
° F.	° C.			
1000	538	0.0366	0.035	0.6
1100	594	0.0460	0.039	0.9
1200	649	0.0527	0.042	1.3
1300	704	0.0597	0.046	1.7
1400	760	0.0668	0.049	2.3
1500	815	0.0733	0.053	3.0
1550	843	0.0765	0.055	3.5
1600	870	0.0796	0.056	3.9
1650	898	0.0840	0.058	4.5
1700	926	0.0881	0.060	5.0
1750	954	0.0926	0.062	5.6
1800	982	0.0970	0.064	6.3
1850	1010	0.0994	0.065	7.1
2400	1316	0.122	0.085	20.0

(*a*) Based on wall 12 inches thick (9 inches of silica + 3 inches of kieselguhr).

(*b*) Door open all the time.

Thus it will be seen that this furnace will require 55.7 kilowatts for operation. No factor of safety need be applied to this figure if the conditions selected are at the maximum. On the contrary, if these are normal operating conditions a factor of safety should be applied according to the possibilities of greater demands being made on the furnace.

After calculating the number of kilowatts necessary for operation, the length of the resistor is approximated in order to determine the voltage. With granular graphite[2] experience has shown that the most satisfactory voltage is equivalent to 1½ volts per inch length of the resistor. From this voltage and the wattage as computed above, the number of amperes may be easily determined.

The electrical resistance of a resistor in a furnace cannot be sufficiently closely predicted to warrant calculating the size of the resistor with a very great degree of certainty. Of necessity, therefore, the exact voltage which will be required for a furnace to take a certain number of kilowatts can be determined only approximately. A provision for obtaining various voltages is, therefore, necessary, and a transformer with several taps is ordinarily employed for this purpose. However, it is perfectly possible to provide a variable voltage generator for the same purpose. Since the precise production of steel for a given furnace cannot be very closely ascertained, and since, in most cases, different productions are desired at different times, it is absolutely necessary that provision be made for altering the kilowatt input at will of the operator.

The usual and satisfactory method of meeting these requirements appears to be the employment of a transformer with 10 to 15 taps. Usually 13 is a satisfactory number, having a range of voltages on the secondary from a minimum equivalent to one volt per inch length of the resistor to a minimum equivalent to two volts per inch length of the resistor. The various taps on the transformers used in most instances have given voltages which are in arithmetical progression, but it is the opinion of the writer that a progression of voltages in equal steps is best suited for the work. For the purpose of making provision for the uncertainty of the resistance of the resistor, the voltages would logically be chosen in arithmetical progression. For purposes of regulation, however, since the kilowatt input increases as the square of the voltage, it would appear, from this point of view, that the voltage steps should be graduated to best meet this condition. The two conditions must be met, and the most satisfactory arrangement is to make the steps in such progression that the difference of the kilowatt input on adjacent taps in the higher voltages will not be so very much larger than on the adjacent taps on the lower voltages. Accordingly, a satisfactory range of potentials on a transformer with 13 taps would have voltages equivalent to the following, per inch length of the resistor: 1.00, 1.10, 1.20, 1.29, 1.38, 1.47, 1.56, 1.64, 1.72, 1.80, 1.87, 1.94, 2.00.

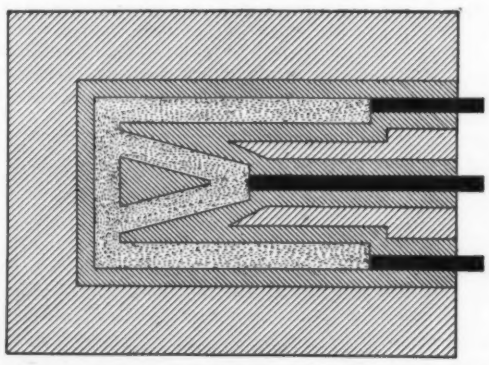


Fig. 4.—Furnace regulated by voltage and resistance; suitable for 4 to 10 square feet hearth area.

ELECTRICAL REGULATION WITHOUT TRANSFORMER.

A method[3] for obtaining this regulation and adjustment without the use of a transformer has been devised in the writer's laboratory very largely through the work of Mr. Richard S. Bicknell. In this type of furnace several resistors are employed, which are not permanently electrically connected, and which by means of suitable switches may be connected in various ways while the furnace is in operation. They may be arranged in series, in parallel or in any combinations necessary to effect the desired regulation. In other words, this is regulation by altering the resistance of the resistor as contrasted with the aforementioned method where regulation was affected by altering the voltage impressed upon the resistor. As will be shown subsequently this type of regulator is particularly adapted to furnaces having 10 square feet of hearth area or over. An example of a furnace capable of such regulation is shown in Fig. 3. With these four resistors in this particular furnace it is possible to obtain 110 inches in length of resistor, or equivalent of same, in the circuit at one time, and 220 inches in length of resistor at another. A large number of intermediate lengths of resistor between this maximum and mimimum figure may also be placed in operation. This particular furnace is designed to operate on 220 volts and it will be readily seen that the maximum voltage obtainable per inch of resistor is two volts and the minimum is one volt. A quite surprisingly large number of intermediate lengths of resistor are obtained by employing the four T-shaped resistors, as shown. The length of the resistor is, of course, merely another way of stating the resistance of the furnace. These T-shaped resistors have each three unequal legs. Resistors *A* and *D* are similar and *B* and *C* are similar, but *A* and *B* have corresponding legs of different lengths. The resistance of the furnace resistors for a number of intermediate steps is made by connecting two legs in parallel in instances when a low resistance is desired. When a high resistance is wanted the resistors are run in series the current passing through the longest legs only. By properly proportioning the legs, it will be seen that the number of intermediate steps for purpose of regulation may be made as large as desired.

It is, of course, possible to combine these two methods of regulation, namely by voltage and resistance, having a few steps on the transformer and having one or a few resistors capable of being arranged either in series or parallel. A furnace so regulated is shown in plan in Fig. 4 and the method is quite suitable for small furnaces of from 4 to 10 square feet hearth area. The construction of the resistor as shown in vertical section would be quite similar to that in Fig. 3.

This discussion applies to both types of furnaces where the two methods of regulation are employed, i. e., either altering the voltage or the resistance. It has been found that a resistor placed beneath the hearth can be composed of two layers of materials to advantage, the upper of granular graphite and the lower of some material of lower electrical conductivity than graphite, such as charcoal. The lower layer takes a smaller part of the current than does the upper layer of graphite, thus placing the major part of the heat liberated quite near to the top of the resistor. This method seems to protect the part of the lining upon which the resistor rests. It protects it sufficiently well not only to warrant its use, but to make its use absolutely necessary in the case of furnaces operating close to or above 1,800 deg. Fahr. A resistor consisting of half charcoal moderately tamped by hand and half graphite gently tamped in is very satisfactory.

The width and depth of the resistor should be such that as much heat as possible is liberated in the desired direction. For resistors in the hearth this direction is, of course, upward. According to the theory, therefore, the logical shape of resistors of this sort would be as wide as possible and quite shallow. This section, however, is not at all feasible for several reasons. The resistor burns away more rapidly when it is wide and it is more difficult to spread the graphite on a wide resistor when it is replenished. Wide resistors require more lining and the expense of the lining is a relatively important item in the cost. When wide resistors are made to run at right angles the current has a tendency to flow across the interior corner in much higher intensity than at the exterior corner. Sometimes carbon or graphite blocks have been placed in the resistor at the corners for the purpose of reducing this local effect. This, however, is not a very good remedy, as the heat liberated in any event is not so great per unit area of the resistor in the corner as in other parts of the furnace. The cross-section of the resistors had, therefore, better be made about square, or wider than the depth by a small amount. If possible the resistors should not be narrower than their depth, but it is impossible to observe this requirement in all cases. Resistors less than 2½ inches wide should not be used. They should be not less than 6 inches deep and preferably about 7 inches, except for resistors over 10 inches wide which can be made 8 inches deep, though more than this is likely to cause excessive heating in the base of the furnace.

The designer frequently has the opportunity of employing one large resistor or two smaller ones to do the same work. Small resistors less than 3 inches wide should be avoided because slight variations in shape have a more marked effect on their resistance than in the case of the large resistors. It is much better as a rule to employ a short resistor 4 or 5 inches wide than a correspondingly longer one 2½ or 3 inches wide. On the other hand, large resistors are also to be avoided. Since the thermal conductivity of graphite is rather low it is evident that large resistors are much more likely to become excessively heated in their centers than small ones. Resistors 6 to 9 inches wide are to be used wherever possible, and for resistors of this type 12 inches wide and 8 inches deep are about the maximum dimensions for furnaces used for heating steel. This is quite too large, however, for any heat-treating work, but it is mentioned merely to give an approximation of the maximum limitation of this type of furnace. A 12 by 8 inch resistor would carry 1,000 amperes and a number of them could be arranged in a furnace so as to liberate 16 kilowatts per square foot of hearth. This is equivalent to a production of about 110 pounds of steel heated to 1,700 deg. Fahr. per hour per square foot of hearth under the usual conditions. This production is not only more than is usually desired, but is far too much for good work. Experience has shown that a maximum production of about 50 pounds per hour per square foot of hearth at 1,700 deg. Fahr. is all that can be expected in electric heat-treating furnaces.

(To be concluded.)

[2] Artificial graphite averaging ¼-inch mesh, but containing no fine powder.

[3] Patented.

The Arrow Rock Dam

By Chas. J. Lisle

ANOTHER "highest dam in the world" is being built by the United States Reclamation Service, and surpasses its record-breaking construction of the Shoshone dam in Wyoming and the Roosevelt dam in Arizona.

This new project, the Boise-Payette project in Idaho, is the outcome of a long effort on the part of the Idaho legislators to get the Reclamation Service to take up the storage problem for the waters of the Boise river. The government has been at work for some years on the reclamation of Idaho lands that will be served by this new dam, and has furnished water through the great Deer Flat reservoir, in which is stored some of the Boise river flood water. But the water supply has not been adequate, and not nearly all the land that must be watered from this project, if at all, has a water supply, except as the reclamation service supplies it.

The Boise river comes from the central Idaho mountains, through a narrow, precipitous gorge, which at various points furnishes excellent sites for storage dams. It was determined to build the storage dam at Arrow Rock, a point on the river about 32 miles from Boise. Work was begun two years ago, after an exhaustive preliminary survey.

The dam is to be 351 feet in height, with arch upstream, and is built of concrete, reinforced. The foundations go 80 feet below the river level. It is 100 feet wide at the base, has a bottom length of about 400 feet, and will be 1,060 feet in total length on top. It will contain 530,000 cubic yards of concrete. It will store water to a depth of 330 feet, and the back-water will extend for 20 miles up stream, making a beautiful mountain lake. It will store 230,000 acre feet of water.

The water is to be taken out through a series of five hydraulically controlled gates, 40 feet above the bottom of the structure. When the dam is full the water will come out at a head of 300 feet, and the gates must be of the heaviest character, and 1,000 tons of steel was used for the gates and accessories. They open into steel penstocks that carry the water through the body of the dam. As the needs of the irrigation season are so fluctuating, a wide range of control is provided. The dam could be practically emptied within a few weeks, if necessary.

Prior to the beginning of the actual work on the dam, the river was diverted from its natural bed, and carried through two 12-foot tunnels 1,000 feet long, cut through the rocky point which forms the west foundation of the dam. These tunnels are large enough to carry more then the highest known discharge of the river at flood time; and will be used for nearly a year longer, as it will take that long to complete the dam. The spillway is cut through solid rock some hundreds of feet from the end of the dam, so that there can be no cutting away of the structure by the action of the water.

A force of from 200 to 1,000 men have been at work steadily ever since the work was begun; and about 800 are now on the job. An interesting feature of the work has been the use of electricity from the government dam farther down the river, to furnish light and power for the work. The earlier dam was put in to divert the water to the government canals for the first part of the reclamation project; and later a power plant was put in, which now furnishes part of the power for the city of Boise, as well as for the building later of the greater dam. The only governmentally owned railroad in the Western hemisphere connects the Arrow Rock works with the outside world. It is 21 miles in length.

Coffee-Growing in Paraguay

THAT coffee can be cultivated in Paraguay is now being demonstrated by the success of a few small plantations in the Department of Altos, a short distance northeast of Asuncion, in the chain of hills extending from Brazilian territory as far west as the Paraguay River. For many years coffee has been produced in small quantities by Paraguayan householders for their own use. Until, however, the success referred to above, only failure has resulted from the efforts of those who have attempted to cultivate the tree for commercial purposes, largely because they neglected to study local conditions and adapt cultural methods thereto. Success has now been attained in the same localities where earlier efforts met with failure. According to Prof. Charles Fiebrig, a botanist of recognized authority and director of the Agricultural College of Paraguay, there are sufficient trees under cultivation in the Department of Altos to yield at present an annual crop of more than 330,000 pounds of coffee. The product is all marketed in Asuncion, where it is sold as Brazilian coffee. The producers of this coffee are Paraguayans, and it is noteworthy that this is the first result of anything like intensive cultivation, requiring a number of years to bring their work to fruition, by the people of this race. Prof. Fiebrig states that the region where the coffee trees are grown seems to meet all the requirements of the plant. The depth of soil, the rare occurrence of frost, which is never sufficient to endanger the plant, the general elevation of the land, and the abundance of trees giving the kind of shade necessary, all contribute to assure success if practical methods and the proper degree of care are employed. It is estimated that 500,000 trees will soon be in bearing in the Department of Altos. As much as 11 pounds have been gathered from a single tree, but this is exceptional. Ten thousand trees is the largest number on any one plantation, the average being 1,500 to 2,000.—*Journal* of the Royal Society of Arts.

Handling Rails Cheaply

ON some railroads rails are being loaded and unloaded mechanically instead of by hand. The machines used are operated by air pressure and usually handle a rail a minute, although in one case it is reported that three rails are being handled in that period. Modern locomotives have sufficient air capacity to provide power for the continuous brakes and the lifting machinery also; but where older engines are used a temporary steam pipe was coupled from the engine to a special pump for handling the rails. Where rails are so dealt with large gangs of men may be dispensed with. One company has been using electromagnets for handling rails and scrap, and it is said that these will lift twelve rails at a time or several tons of spikes. The magnets are operated from the jib of a crane, usually of the locomotive type.

View of the great Arrow Rock Dam, showing spillway cut in solid rock around the end of the dam.

Calorizing*

A Protective Treatment for Metal

By H. B. C. Allison and L. A. Hawkins, Research Laboratory, General Electric Company

SINCE the close of the bronze age iron has been used for ovens, utensils and tools of every kind for all temperatures up to dull red; but for higher temperatures there has been, even up to the present day, no cheap metal available. Platinum, because of its cost, has been quite limited in application, and the cheaper metals, such as copper, and most of the alloys, such as brasses and bronzes, will not withstand heating in the air to

(a) Uncalorized iron pipe.

(b) Calorized iron pipe.

Fig. 1.—A piece of plain iron pipe and a piece cut from the same tube but calorized, after being subjected to the same degree of temperature for the same length of time.

red heat. Nickel and cobalt are the most stable of those metals which may be worked or cast and are fairly cheap and will withstand moderately high temperatures. Some of the alloys containing nickel are also quite permanent in the air at red heat.

Mr. T. Van Aller has discovered a process of heating metals in revolving drums with mixtures containing, among other things, finely divided aluminium, by which a surface alloy containing aluminium is produced. In the case of copper, this alloy is of the nature of an aluminium bronze, but richer in aluminium than the ordinary alloy of that name and more resistant to heat, so that copper thus treated is protected, up to the melting point of the alloy, from the scaling which occurs when

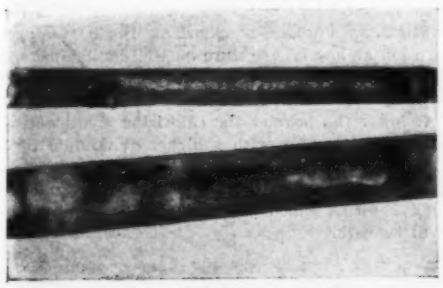


Fig. 3.—A section of calorized iron pipe (lower) and a section of uncalorized iron pipe (upper) after being treated to operating temperature for 400 hours.

untreated copper is heated above 300 deg. Cent. The same general result was obtained in the case of iron and steel. Some use was made of this process, which has been called "calorizing," for treating copper soldering irons and iron resistance wires for heating devices.

Modifications of the process, extending it to further applications, were made by Mr. E. G. Gilson of the Schenectady Research Laboratory. Pieces which, because of their shape or size, are not adapted for tumbling, may be calorized by packing them in, or painting them with, a suitable mixture, and heating them. Thus, the size of the heater is the only limitation on the size of the piece that may be calorized. Wire or ribbon may be treated by a continuous process, by passing it through a heated pipe containing the proper calorizing mixture.

There appear to be many places where it is desirable to use iron vessels or apparatus at temperatures above red heat, and at such temperatures ordinary iron rapidly oxidizes and scales away. After iron is calorized the effect of heating is slight. Instead of burning and the scale falling off, as in the case of untreated iron, practically no effect can be detected after a considerable time—certainly none which injures the surface. This is well illustrated by the two pieces of iron pipe shown in Fig. 1, both from the same kind of pipe, but one of which (B) was calorized. The two were heated side by side, with an ordinary laboratory blast lamp to a temperature of about 900 deg. Cent. for a period of four hours, then cooled and the heat once more applied for another period of four hours. At the end of that time the untreated pipe (*a*) was badly burned, the point where the flame was directly applied having been reduced to one half the original thickness, while the whole surface was blistered. The contrast between this piece and that which was calorized (*b*) is very marked, for even upon close examination the calorized pipe appears to be unchanged.

In connection with the piece of calorized pipe used in this experiment, it should be stated that it had previously been used in other work, where it had been alternately heated to 1,000 deg. Cent. and cooled in an electric resistance furnace open to the air. The total time during which the maximum temperature was maintained was about fifty hours. A rather extreme test has been applied to this same piece lately, by heating it to about 900 deg. Cent. and plunging it into cold water, after it had cooled to a dull red. This has been repeated three times and the surface shows no signs of cracks or any tendency to scale.

Fig. 2 shows a similar comparison between two pieces of sheet iron tube, one calorized and the other not, which were both subjected to a temperature of 800 deg. Cent. in a gas furnace for 100 hours. The uncalorized piece is practically destroyed, while the calorized piece is unharmed.

As evidence of the performance of calorized iron under actual working conditions, the tubes shown in Fig. 3 were photographed. These tubes are part of a small nitrogen purification plant which is in use during each working day. They are both heated by gas in a brick furnace, the larger tube to a temperature of about 800 deg. Cent. and the small to about 650 deg. Cent. The larger tube was calorized and has been in use over 400 hours with no observable deterioration, while the smaller tube, which was not calorized and which has also run 400 hours, is badly burned. The spots on the calorized tube are carbon deposits due to poor combustion in the burners. In Fig. 4 are shown these same tubes after they have run over 650 hours. The calorized tube still shows no evidence of scale while the other tube is almost burned through.

Another application of this process is to iron wire or ribbon such as is used in electric heating units. An untreated piece of this ribbon will burn out in four or five hours at the most, whereas tests upon calorized pieces have shown that the life is increased at least fifty fold, and in the best instances over one hundred fold. The results of tests made at Pittsfield indicate that a life of over 500 hours may be expected from calorized heating units run at a temperature of 800 deg. Cent.

Calorized seamless iron tubing is being used for combustion tubes in the research analytical laboratory where pure oxygen is brought in contact with the metal at temperatures from 900 to 1,000 deg. Cent. These

Fig. 2.—Effect of 800 deg. Cent. in a gas furnace for 100 hours on a section of calorized and of uncalorized sheet iron tubes.

have thus far operated all right and still appear unaltered after nearly 100 hours' use.

The above facts seem to indicate that this is a simple method for extending the use of iron under oxidizing conditions at high temperatures, and for greatly prolonging the life in those instances where it is now used, but must be renewed at frequent intervals. In the case of small muffles or crucibles, where temperatures are below 1,000 deg. Cent., this treatment of cheap cast or wrought iron shapes seems very promising. While the life of the coating depends on the temperature at which it is used, as well as on the duration of time taken in its preparation, i. e., the quantity of aluminium which alloys with the surface of the iron, it does not permit of long use at temperatures much in excess of 1,100 deg. Cent.

Copper parts also, which are exposed to high tem-

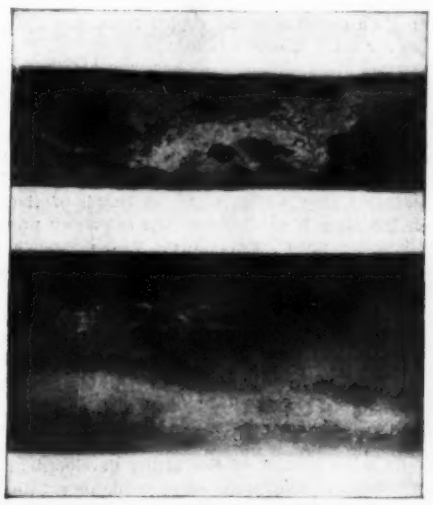


Fig. 4.—Photograph of the same tubes as shown in Fig. 3 (upper uncalorized), but after 650 hours at operating temperature.

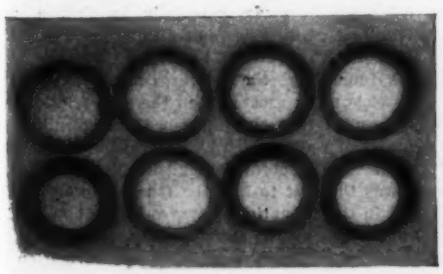


Fig. 5.—Cross-sectional view of several 1¼-inch diameter copper rods after being calorized for two hours.

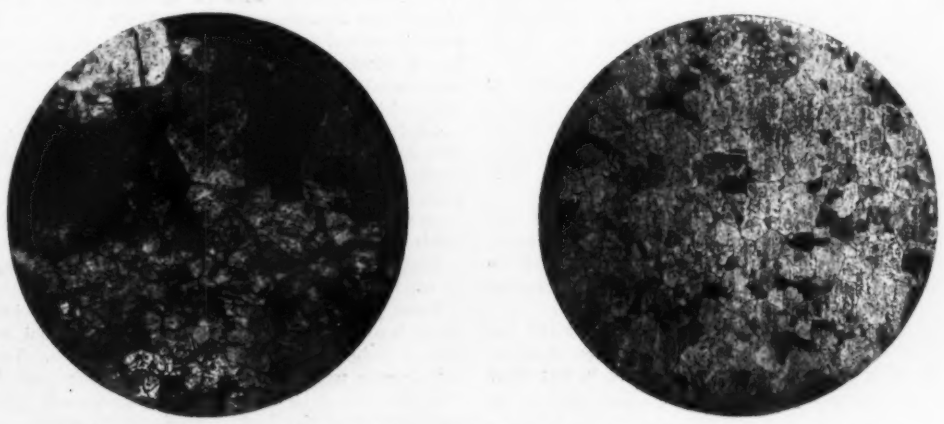


Fig. 6.—Photo-micrographs (55 dia. magnification) of sections of a calorized copper bar.

* From the *General Electric Review*.

peratures, can have their life increased by calorizing. In some cases calorized copper may be used advantageously in place of aluminium bronze. For instance, a large power station had trouble from early corrosion of its condenser tubes. These tubes were aluminium bronze and were supposed to last at least a year. As a matter of fact, while occasionally tubes would last as long as six years, other tubes would fail in four to six weeks after they were installed. About two and a half years ago a set of calorized copper tubes was installed and so far not a tube has failed.

In some cases the life of copper contacts can be increased by calorizing. For instance, a set of railway controller contacts which were calorized showed double the life of the ordinary untreated contacts.

As has been said, the effect of calorizing is to produce a surface alloy containing aluminium. The thickness of this alloy varies with the length of time to which the piece is subjected to the calorizing process, and the percentage of aluminium varies through the coating being greatest at the surface. This is shown clearly by a cross-section of a calorized copper rod. The line between the alloy and the unchanged copper is sharp, but the color of the alloy varies from a rich golden-yellow next to the copper to a silvery-white at the surface.

Fig. 5 shows cross-section views of a number of copper rods 1¼ inches in diameter, which were calorized for about two hours.

Fig. 6 shows two cross-sectional photo-micrographs of a calorized copper bar. These photographs are magnified fifty-five diameters. One of them shows the large crystals of the calorized surface, and the other shows the unaltered crystalline structure of the copper a short distance below the surface. In the first of these photographs the blistering of the copper immediately below the calorized surface is shown by the spaces between the crystals of copper. This effect is characteristic of calorizing.

Fig. 7 shows cross-sectional photo-micrographs magnified forty diameters of an iron pipe which was used for some time as a heater for calorizing wire by the continuous process above mentioned. This pipe was packed with calorizing mixture, and its inner surface was therefore subjected to long calorizing treatment.

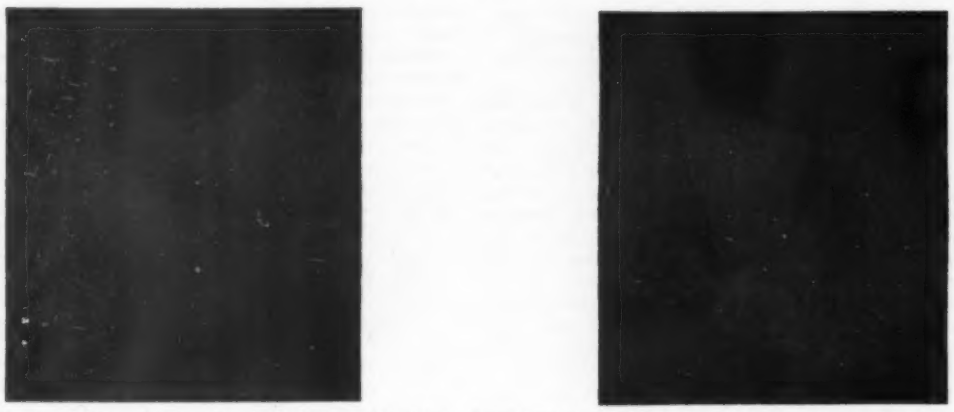


Fig. 7.—Photo-micrographs (40 dia. magnification) of sections of an iron pipe which has been subjected to calorizing action for a long period.

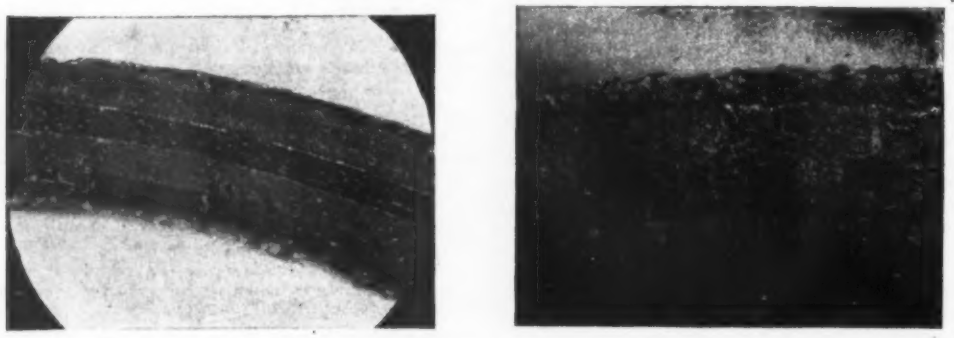


Fig. 8.—Photo-micrograph (20 dia. magnification) of cross-sections of an iron tube calorized at high temperature with a mixture rich in aluminium. Left-hand view, before heating; right-hand view, after heating at 1,100 degrees for 50 hours.

If the calorizing process is conducted at a high temperature in a mixture rich in aluminium, two layers of different alloys may result. Fig. 8 shows photo-micrographs, enlarged twenty diameters, of a cross-section of an iron combustion tube thus calorized. The first figure shows three layers, or rather five. The outer layers are probably mostly aluminium with a little iron, the next aluminium and iron with the iron predominating, and the middle layer the unchanged iron. The lines bounding the middle layer are especially sharply defined. The second figure shows the same tube after heating in the air at 1,100 degrees for 50 hours. The sharp lines bounding the middle layer have disappeared and the crystals now have a radial structure. This is characteristic of all samples fired at this high temperature, and is due to a diffusion of the aluminium into the iron, making a more homogeneous structure. The outside layer is still distinct, however, and this is probably due to the oxidation of the aluminium.

When an iron pipe or ribbon is calorized for a heating unit, a portion of the iron becomes alloyed with the aluminium. Naturally this results in changing both the resistance and the temperature coefficient. The thicker the calorizing coat the greater is the change. This is shown by the following table, in which No. 1 was given a lighter coat than No. 2.

Sample.	Ohms per M. (19°)	Temperature Coefficient Electrical Resistance (0–150°)+10⁻³
Iron Ribbon.....	0.905	5.61
Same calorized, No. 1.....	2.45	1.72
Same calorized, No. 2.....	7.6	0.151

A thin ribbon may easily be calorized all the way through, and then becomes quite brittle.

The dimensions and weight of either a copper or iron piece are slightly increased by calorizing. The increase of dimension is much less than the thickness of the alloy coat, the greater part of which simply takes the place of the original metal. The dimensions may, however, increase several mills, and there is a tendency to a greater increase at the edges than on flat surfaces.

For iron, calorizing is intended only for protection at high temperatures. It does not compete with galvanizing, sherardizing, and other similar processes for protection against oxidation or corrosion at low temperatures. Its usefulness lies within a range of temperature much higher than a galvanized or sherardized coat could stand. For copper, calorizing is effective against corrosion at low temperature as well as against oxidation at high temperature. The upper limit is determined by the melting point of the alloy, which is somewhat lower the heavier the calorizing treatment, since that means an alloy with a higher aluminium content.

The probable explanation of the effect of the aluminium in the surface alloy is that a thin coat of alumina forms which prevents further burning of the metal beneath.

The Resistance to a Ship's Motion*

As Determined Experimentally by Means of Models in Special Tanks

In no other branch of the highly developed art of shipbuilding are the results of scientific observation so important as they are in the determination of the resistance opposed by the water to the vessel's progress.

This resistance determines the form of the hull and the power required to maintain a given speed. The laboratory of the chemist or physicist finds its counterpart in the experimental basin in which the shipbuilder tows small models of vessels and measures the resistance opposed to their motion.

Such experiments were less needed in the days of wooden sailing vessels because the best forms of hulls had been determined by the experience of centuries. The wooden sailing ship attained its highest development in the swift clippers of the middle of the nineteenth century.

The introduction of iron as the material of construction, and steam as the motive power, made it necessary to study closely the influence of the form of the hull upon the resistance, and to establish exact relations between engine power and speed.

The problem of resistance, however, attracted the attention of scientific pioneers 250 years ago. Newton, Bernouilli and Euler attempted to solve it, but their results were too greatly at variance with those of experience to have any practical value.

In the year 1770 the French Academy of Sciences appointed a commission composed of Bossert, Condorcet, and d'Alembert, to collaborate with Borda, who had been working on the problem seven years, in the establishment of a formula for the construction of a hull of minimum resistance. The possibility of discovering a mathematical formula applicable to all conditions of length, width, and speed was generally assumed during the succeeding one hundred years, and this view, though disposed long ago, is still often expressed.

Admiral Shévenard, following Borda's example, experimented with prisms, cylinders, and other simple forms. Subsequently (1775 to 1794) the Swedish engineer, Chapman, investigated the variation of the resistance with the position of the greatest cross-section in solids of rotation, 25 inches long, with paraboloidal and conical ends, but his researches produced no results of value.

A few years later (1793 to 1798) the English colonel, Marc Beaufoy, experimented with floating and submerged bodies in the Greenland dock, London. These experiments mark the first rational attack upon the problem, and it is interesting to compare the means employed with the highly developed apparatus and methods of the present day. A contemporary drawing of Beaufoy's apparatus is reproduced in Fig. 1. The power required for towing the model through the water was furnished by the fall of a heavy weight from a scaffold about 60 feet high. The motion of the falling weight was transmitted to the tow line by a multiplying train of pulleys, while the time and velocity of fall were measured automatically by the trace of a pendulum on a bed of sand. The models were made of wood, and were painted, for Beaufoy's first object was to determine the frictional resistance.

Many experiments of the same general character were subsequently made, especially in France, with models and even with ships, but all of these researches started from false premises.

It was found that the total resistance experienced by a vessel is much greater than the skin friction, and it was assumed that the difference is determined by the quantity of water which is thrust aside by the moving vessel. The celebrated English shipbuilder, Scott Russel, was the first to find the true cause of the discrepancy, in the formation of waves at the bow, and of waves and eddies at the stern of the vessel.

With the rapid development of steam navigation the resistance to motion, and the form of hull best adapted to minimize that resistance, assumed an importance

* Translated from Prof. Hermann Wilda's article in *Die Umschau*.

that may be estimated from the fact that, for a given size and speed, the well designed ships of to-day develop only half as much resistance and burn half as much coal as the ships of thirty years ago.

The first really scientific attempt to solve the problem was made in 1870, when the elder Froude began his celebrated experiments with models geometrically similar to the vessels which were to be built. Scott Russel, the most famous shipbuilder of his time, asserted that the resistance experienced by real ships could not be correctly deduced from such experiments, but Froude found that the 878-ton sloop "Greyhound," when towed at various speeds and drafts, developed resistances that agreed exactly with the results obtained with a model having one sixteenth the linear dimensions of the sloop. The conclusions that Froude drew from his experiments, on the basis of the laws of similarity that had been enunciated by Newton, are still of practical validity as they undoubtedly agree very closely with the facts.

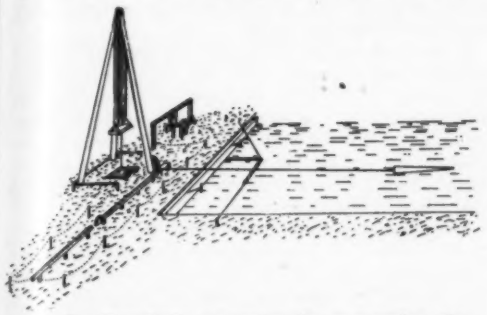


Fig. 1.—Beaufoy's apparatus for measuring the resistance opposed by the water to the motion of vessels.

In order to obtain correct results the weight of the model and the speed with which it is towed in the experimental basin must bear certain definite ratios to the contemplated speed and tonnage of the ships. For example, a model of the "Imperator," constructed on the scale of 1 to 50, must weigh 368 kilogrammes, a result obtained by dividing the displacement of the "Imperator," 46,000 metric tons, by the third power of 50.

The proper speed for the model, 1.73 meters per second, is obtained by converting the vessel's speed, 24 knots, into meters per second, and dividing the result by the square root of 50.

Several plans are drawn for the projected ship, and models constructed according to these plans are tested in the experimental basin in order to ascertain which develops the smallest total resistance.

The models are made of paraffin, to which a little wax is added. The mixture is melted in a water bath and poured into clay molds, with cores, producing hollow vessels with walls about two inches thick (Fig. 2). After the model has cooled it is taken from the mold and placed, in an inverted position, on the carriage of the shaping machine (Fig. 3). In this machine the model is moved longitudinally beneath two cutting wheels *n n*, which turn on vertical shafts *s s*, equidistant from the median plane of the model. The cutting wheels, as the model moves lengthwise beneath them, are gradually raised or lowered by means of their connection with an arm resting on the guide *w*, which represents a longitudinal vertical section of the vessel, at a certain distance from the median plane. For reasons of economy and convenience, the dimensions of the guide *w* are made smaller than those of the model. The table *t*, which carries the guide, moves in the same direction as the model, but less rapidly, and the guide arm is connected with the cutting wheels by a pantographic or magnifying mechanism. In this way two symmetrically situated longitudinal sections of the hull are outlined by the grooves made by the cutting wheels. The cutting wheels are then moved toward or away from the median plane, by turning the handwheel *h*, the guide form appropriate to their new position is substituted for the one already used, and the operation is repeated. On leaving the shaping machine the model presents the appearance shown in section in Fig. 4. The form of the finished model is represented by the bottoms of the grooves. The superfluous material, shown in black in Fig. 4, is removed by hand. If the model, when ballasted with bags of shot to the proper draft, has the calculated weight, it is ready for use in the experimental basin.

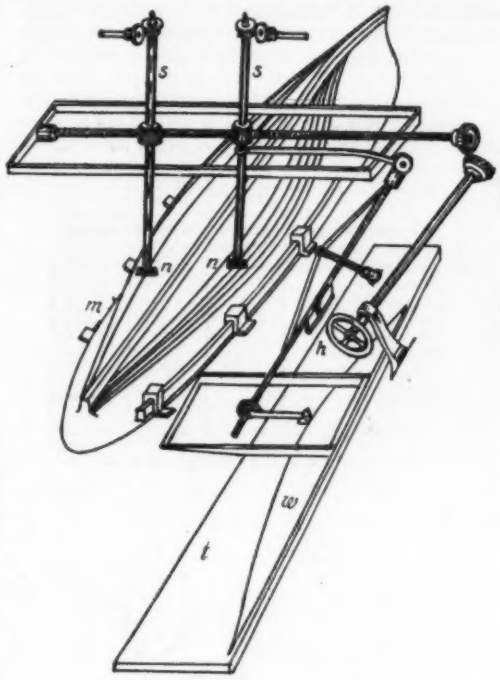


Fig. 3.—The shaping machine.

The basin (Fig. 5) is 40 or 50 feet long and flanked by heavy rails, which support the towing carriage *W*. All of the measuring apparatus is placed on this carriage, which bridges the basin and can be moved at various speeds by electric power.

The apparatus for measuring the total resistance to progression, is indicated in Fig. 6. The model is attached by a tow line to one arm *c* of the iron frame *a b c*, which is pivoted to the towing carriage at *o*. The opposite arm *a* is attached to one end of the dynamometer spring *f*, the other end of which is fastened to the carriage. As the carriage moves, from right to left, the model is drawn through the water in the same direction. The resistance of the water produces a tension in the tow-line, which turns the frame *a b c* about the pivot *o*, and stretches the dynamometer spring *f*. This displacement is multiplied by ten by an aluminium lever pivoted at o_1. The long arm of this lever, one meter in length, carries a tracing point *s*, which presses upon a rotating cylinder. The curve of resistance, thus traced, is a straight line if the speed of the model is kept constant and all shocks are prevented. The function of the spring f_1, between the model and the tow-line, is to equalize the tension and compensate the oscillations of the model. Records of the distance traveled, in five-meter spaces, and of the elapsed time in half-seconds or quarter-seconds, are simultaneously inscribed on the cylinder by appropriate mechanism. The strength of the dynamometer spring, which must be selected in accordance with the size and speed of the model, is measured by weights suspended from the arm *b*. As the three arms, *a b c*, are equal in length, the effect of a weight suspended from the end of *b* is equivalent to that of a force equal to the weight, applied horizontally in the proper direction at the end of *a* or *c*. (The weights *p* are not used in the towing experiments). The apparatus employed for the measurement of resistance in different experimental basins varies in detail, but all of it is based on the same fundamental principle, which was enunciated by Froude.

The force required to drive a screw-propeller, and the pressure exerted upon its blades by the water, are also determined by experiments with small models in basins. The apparatus employed for this purpose is indicated in Fig. 7. The propeller *p* is carried by the frame *a b c d*, which can turn freely on the pivot *o*. The end of the arm *a* is connected with the lever *k*, and the pressure on the propeller is compensated approximately by placing weights *q* in the pan *s*, suspended from the top of the lever. The compensation is completed by the spring *f*, at the end of the horizontal rod *t*, attached to the upper part of the lever. If the compensation is not exact, the lever *k* departs from its vertical position and strikes one of the electrical contacts *k k*, thereby causing the electric motor *m* to rotate forward or backward, and to compress or extend the spring *f* by means of the screw *g*, until the lever is brought back to its position of equilibrium. The pressure on the propeller can then be computed from the weight *q* and the change in the length of the spring *f*. As the contacts *k k* are very near each other the lever *k* cannot depart far from the vertical, and the tracing point *i*, attached to the rod *t*, inscribes a nearly straight line on the recording cylinder. At the same time the torque of the propeller is measured by a torsion dynamometer intercalated in the shafting by which the propeller is driven.

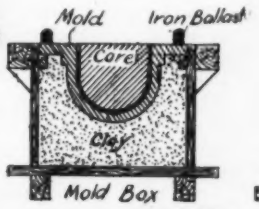


Fig. 2.—The model in its mold.

Fig. 4.—The model as it leaves the shaping machine.

The newest experimental basins are equipped with apparatus for making continuous photographic records of the waves formed by the bow and stern of the moving model.

There are now in existence twelve experimental basins of this general character; two in Germany, four in England, two in the United States, and one in each of the countries France, Russia, Italy, and Japan.

What an Incompetent Workmen Costs

It has been stated that the records of a large manufacturing plant show that it costs on an average $35 to engage a workman, try him out and discharge him for incompetency; and while this is undoubtedly an expensive experiment in ordinary machine work, it will be readily apparent that it may be vastly more so in the case of a power plant, where an incompetent shift engineer might easily cause great damage in case his inefficiency was not discovered before some emergency arose which he was unfit to handle. It is evident that in a large plant a great deal of money may be wasted annually if proper care is not exercised in taking on new men, and to avoid this the personal attention of some experienced man will go much farther than the formal red tape method of having a cheap clerk sort over a miscellaneous collection of complicated "employment statements" which many a first-class workman may not be able to fill in properly.

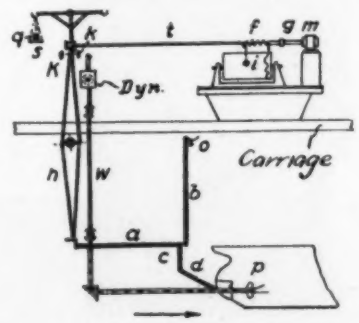


Fig. 7.—Diagram of apparatus for measuring pressure of propeller.

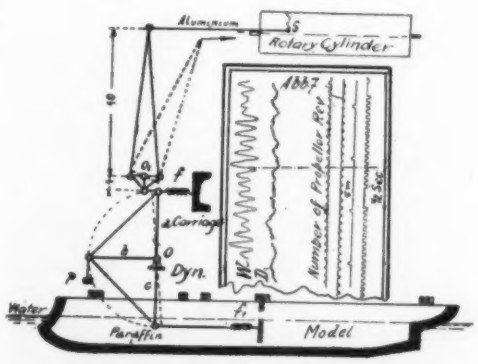


Fig 6.—Diagram of apparatus for measuring resistance.

The insert shows the record on the cylinder, where *W* is the resistance to progression, and *D*, pressure on the propeller.

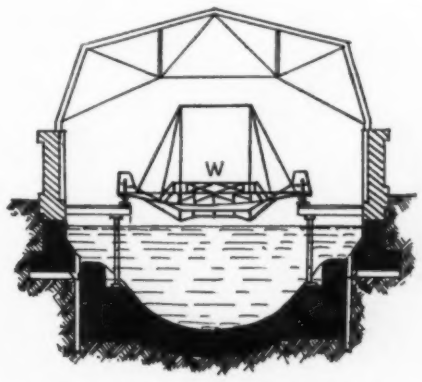


Fig. 5.—Experimental basin and towing carriage.

Producer Gas from Low Grade Fuels*

Cheap Power from Fuels Not Heretofore Considered Economical

THE Reports of the U. S. Geological Survey show that, if the rate of increase of fuel consumption in this country that has held for the past fifty years is maintained, the supply of easily available coal will be exhausted before the middle of the next century. The production of coal in the United States increased from less than twenty million tons fifty years ago to nearly five hundred million tons in 1912; if the industries of the country continue to develop at a sufficient pace to maintain this rate of increase, then the limit of our coal supply will be reached in about 200 years. As a matter of fact, the fuel consumption per capita is actually increasing much faster than the population, so that the question of the continuation of this rate of increase is one of considerable importance.

It is interesting to note that the production of coal in the United States has been for some years greater than that in any other country. The world's production of coal by countries for 1907—the last year for which figures are available to the writer—is given in Fig. 1.

The disposition of the coal fields in this country, as well as the relative areas of the different grades of coal, is indicated in Fig. 2. The limited supply of good coal makes it necessary to mine large quantities of subbituminous coal and lignite to meet future conditions. It will be noted that there is very little over-lapping of the bituminous and lignite areas.

Most of the United States lignites do not weather well, but break down and crumble into fine dust when exposed to the atmosphere for any length of time. There are, however, extensive areas of lignites in Alaska which stand up very well under weather conditions.

A great many low-grade bituminous coals and lignites may be utilized for power purposes by briquetting, and the use of this process industrially is gradually increasing. Briquetting, however, raises the price of the fuel by a considerable amount. It costs 90 cents to $1 per ton to briquette coal, and this large expense is practically prohibitive in competition with cheap fuel. On account of the expense, it appears that briquetted coal will hardly become adopted for large plant work, though this form of fuel undoubtedly serves well under certain conditions for domestic purposes.

Another low-grade fuel is peat. There are large deposits of peat in this country, and in Canada there are some 37,000 square miles of peat area from six to ten feet in thickness. Peat is prepared in Sweden, Denmark, Germany and Russia, and is also secured extensively in Ireland and some parts of Holland. The distribution of peat in the United States is shown in the map, Fig. 3.

When it comes from the bog, peat contains about 85 per cent water, but when "commercially dried" by exposing it to the sun, it contains from 25 to 30 per cent moisture. Commercially, dry peat has a heat value of about 8,000 British thermal units per pound, and is very suitable for use in gas producers, as very little or no steam need be introduced with it.

In view of the necessity of utilizing, for the production of power, grades and varieties of fuels which have not until recently been considered economical, the U. S. Bureau of Mines has conducted a number of investigations on the making of producer gas from such fuels.

The introduction of the gas producer into this country for power plant work was made about the year 1900. In that year the number of installations was very few—perhaps two or three plants—but since then it has steadily increased. The total number of plants in 1911, of which the writer has record, was 660, and of these a large proportion were double installations, which were not counted separately. The number of gas producer power plants in the United States at the present time is probably in the neighborhood of 1,000. The total horse-power of such plants in the United States in 1900 was 2,000; this has increased year by year until in 1911 it was between 160,000 and 170,000, some 80,000 of which was obtained from bituminous coal, some 70,000 from anthracite fuel, and about 10,000 from lignite.

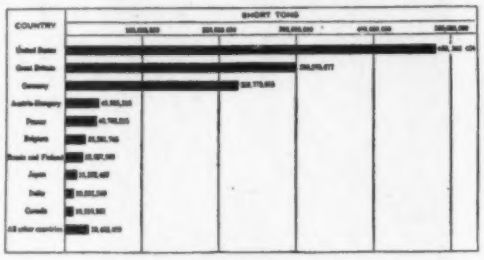


Fig. 1.—World's production of coal.

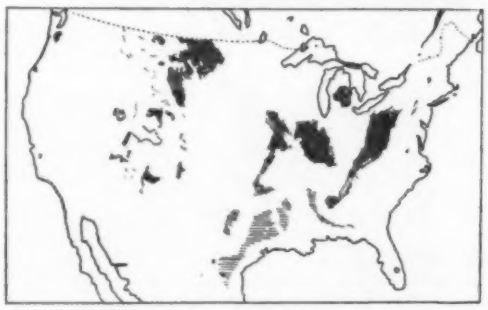


Fig. 2.—Distribution of coal fields in the United States.

Fig. 3.—Distribution of peat in the United States.

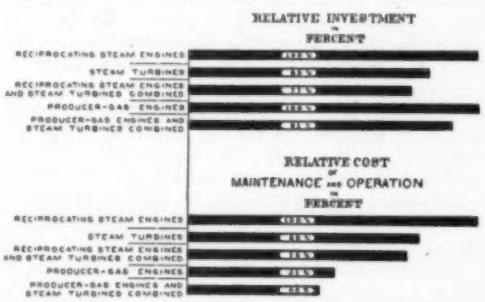

RELATIVE INVESTMENT IN PERCENT
RECIPROCATING STEAM ENGINES
STEAM TURBINES
RECIPROCATING STEAM ENGINES AND STEAM TURBINES COMBINED
PRODUCER-GAS ENGINES
PRODUCER-GAS ENGINES AND STEAM TURBINES COMBINED
RELATIVE COST OF MAINTENANCE AND OPERATION IN PERCENT
RECIPROCATING STEAM ENGINES
STEAM TURBINES
RECIPROCATING STEAM ENGINES AND STEAM TURBINES COMBINED
PRODUCER-GAS ENGINES
PRODUCER-GAS ENGINES AND STEAM TURBINES COMBINED

Fig. 4.—Comparative cost of steam and producer gas power plants.

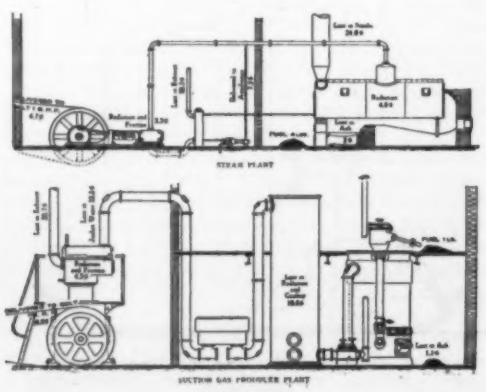


Fig. 5.—Distribution of heat losses in steam and gas plants.

Of the total number of plants operating in 1912, 84.5 per cent used anthracite coal and 10.7 per cent bituminous coal, while lignite was used in 4.4 per cent of the installations. The anthracite plants, however, represented only 47.8 per cent of the total horse-power developed, the bituminous plants 46.3 per cent, and the lignite plants 5.4 per cent, while wood and oil developed the remaining small percentage.

The anthracite plants are scattered all over the country, though several are congregated around New York and Philadelphia. The lignite plants are chiefly in Texas and Washington; there was a marked increase in 1912 in lignite plants in the former of these States. The largest total horse-power is produced in New York, and the next is Missouri.

Factors which influence the installation of any particular type of plant are cost of installation and of maintenance, and economy. The average cost of producer gas installations is about equal to that of reciprocating steam engines; the cost of maintenance is, however, only about one-half, while the economy has been shown in several cases to be from two to three times as great. These statements are illustrated in Fig. 4.

At the Interboro Rapid Transit Company's Fifty-ninth Street Station, New York city, is one of the most efficient steam plants of which the writer has knowledge. At this plant, 970 British thermal units have to be put into the furnace to realize 100 British thermal units at the busbars. In a theoretical gas plant devised on the same scale by Mr. Scott, Superintendent of Motive Power of the Interboro Rapid Transit Company, 100 British thermal units are obtained at the busbars when only 465 British thermal units are charged into the producer.

Representing the figures in the above example in percentages, out of 100 per cent of energy thrown into the furnace of the Interboro Rapid Transit Company's boilers, 10.3 per cent is realized as useful work at the busbars. The theoretical gas plant assumed for comparison would deliver 21.5 per cent to the busbars.

At the Bureau of Mines Testing Station, a 250 horse-power Corliss engine, with 26.6 pounds water rate, with Heine boilers, required 2,060 British thermal units charged into the furnace to secure 100 British thermal units at the busbars, while a gas producer and gas engine, using the same fuel, required only 740 British thermal units to deliver 100 British thermal units at the busbars. In other words, 4.85 per cent of the energy in the fuel charged into the furnace of the steam plant was delivered to the busbars, while 13.5 per cent of that charged into the producer was delivered in the same way.

From a series of tests on a number of different Illinois coals, a comparison of the quantity of fuel per horse-power hour required in the steam plant and in the producer gas plant at the Bureau of Mines showed that, on the average, the former required 2.6 times as much as the latter. With fuel ranging in heat value from 14,000 to 15,000 British thermal units per pound, the gas plant

Fig. 7.—Gas producer with revolving grate.

* Abstract of lecture delivered at a stated meeting of the Franklin Institute by R. H. Fernald, M.E., Ph.D., Consulting Engineer, U. S. Bureau of Mines; Whitney Professor of Dynamical Engineering, University of Pennsylvania, Philadelphia, Pa., Member of the Institute, and reported in its Journal.

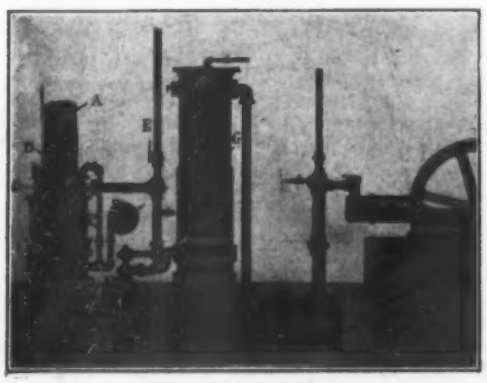


Fig. 6.—Simple form of suction producer.

consumed approximately one pound, and the steam plant approximately three pounds per horse-power hour. Similarly, with fuels ranging between 7,000 and 8,000 British thermal units per pound, the gas plant consumed 2¾ pounds per horse-power hour while the steam plant required 7 pounds. These figures represent the average of a large series of tests of coals and lignites from different sections of the country. The following results were secured under similar conditions at each of these plants.

Two and nine tenths pounds of West Virginia run of mine coal containing 2.4 per cent moisture per brake horse-power per hour were required in the steam plant, while the gas plant required but 0.85 pound of the same coal.

With New Mexican run of mine coal, containing 19.6 per cent ash, the gas plant required 1.1 pounds per brake horse-power hour, or just a little more than of the highest grade West Virginia coal, and very much less than the steam plant with West Virginia coal.

With West Virginia bone coal containing 44 per cent ash which came in such form that a great deal of it resembled rock and, when struck with a hammer, threw out sparks, only 1.66 pounds per horse-power hour were required.

Many such fuels as the above can be utilized in producer gas plants, which require, as indicated, much less coal per horse-power hour than the corresponding steam plant.

Lignites usually run high in moisture, but make a gas of excellent quality. Less lignite was required per horse-power hour in the gas plant than of West Virginia coal in the steam plant.

Fig. 5 shows the distribution of heat in typical steam and gas plants. The heat losses in the two plants are as follows:

STEAM PLANT.	Per cent.	
Heat lost in ashes	2.00	
Heat lost in radiation and cooling	4.60	
Heat lost in smoke	24.60	
Total losses in boiler	31.20	
Heat lost in radiation and friction	3.30	
Heat lost in exhaust	53.50	
Heat lost in jacket water	.....	
Heat lost in auxiliaries	7.30	
Total heat losses in entire plant		95.30
Net efficiency of plant		4.70

GAS PLANT.	Per cent.	
Heat lost in ashes	1.10	
Heat lost in radiation and cooling	18.60	
Heat lost in smoke	.....	
Total losses in producer	19.70	
Heat lost in radiation and friction	4.30	
Heat lost in exhaust	23.70	
Heat lost in jacket water	33.50	
Heat lost in auxiliaries	.....	
Total heat losses in entire plant		81.30
Net efficiency of plant		18.80

Original heat in the coal in both plants = 13,500 units per pound.

There are several types of gas producers now in use, among which are the suction type, the up-draft pressure type, the down-draft type and the double-zone type.

The suction producer is the simplest in form. A typical suction producer is shown in Fig. 6. The operation is as follows: The producer *B* is fed with fuel from the hopper *A*, which is provided with some feeding device so that the fuel may be dropped into the container below without admitting air. *C* is the vaporizer for vaporizing the water and mixing it with the air. The steam-saturated air passes down through the pipe *P* to the bottom of the producer. *D* is the starting fan. The hot gas leaving the producer enters a vertical pipe *E*, the upper part of which can be opened to the air to allow the poorer gas to escape when starting. The gas passes down the vertical pipe through a water seal to the coke scrubber *G*. Tar collects at the bottom of *E* and runs into the tank shown. From the scrubber, the gas passes into the expansion box *H*, from which it is drawn by the piston of the engine into the cylinder.

The gas produced by the use of air and carbon only has certain excellent qualities for power purposes, but is rather low in heat value, and further than that, in making such gas there is a tendency for the temperature to rise to such a point that excessive clinkering is produced and fuel troubles are caused. The introduction of water or steam maintains the temperature at a sufficiently low point to prevent clinker formations.

When producer gas is made from coal, its constituents are carbon monoxide, a limited percentage of hydrogen and a small amount of marsh gas. Carbon monoxide is the main constituent.

Some gas producers embodying special features are shown in Figs. 7 and 8. The producer illustrated in Fig. 7 has a revolving grate and an automatic feed. That shown in Fig. 8 is a mechanically-poked continuous gas producer.

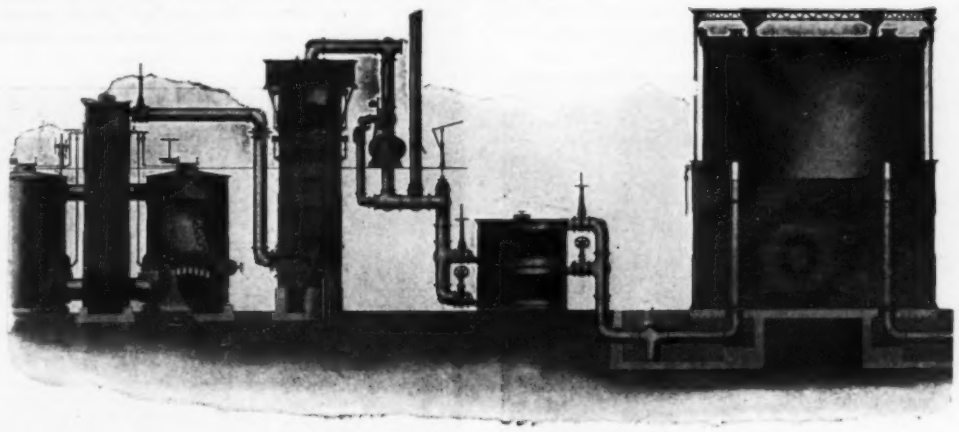


Fig. 9.—Producer plant that converts the tar into gas.

A number of gas plants are provided with centrifugal tar extractors, for removing tar. Getting rid of this tar after it is removed is a very serious problem, and many attempts are being made to effect an increased utilization of this product commercially. Fig. 9 shows a system in which arrangement is made for converting the tar into gas available for use in the engine. The method is to run two generators on a certain grade of fuel. The bed is a layer of coke; the fire is built on top of this and green coal is charged in over the fire. By this means an incandescent bed is formed. The draft produced by the exhauster draws the gas downward from the green coal through the incandescent bed, and the tarry compounds are supposedly converted into gas. The products are then drawn through the wet and dry scrubbers to the holder. As shown in the figure, the exhauster is situated between the wet and dry scrubbers.

With the above system, after a certain period of operation, the tarry compounds, dust, soot, etc., tend to clog the fuel bed and the pull on the exhauster increases. Under normal conditions, the average pull is from 5 to 6 inches of water, increasing steadily. When the pull has risen to about 20 inches, the process of "shooting the bed" is gone through. The charging doors and the gas valve are closed, and steam under 60 to 80 pounds pressure is turned on under the grate. This jet of steam shakes up the whole fuel bed and sends the dirt, dust, soot, etc., through the by-pass into the other gas generator. After the process is completed the gas has a heat value of about 200 British thermal units instead of 105 British thermal units.

A double purpose is served with this type of plant, as two kinds of gas are produced—the first being commonly called air gas and the second water gas.

The system is used by a company in Boston which, however, requires no water gas, but simply gas for the

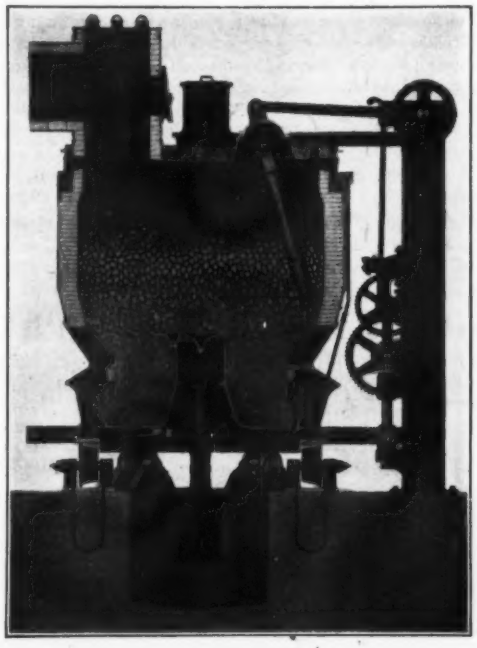


Fig. 8.—Mechanically-poked producer.

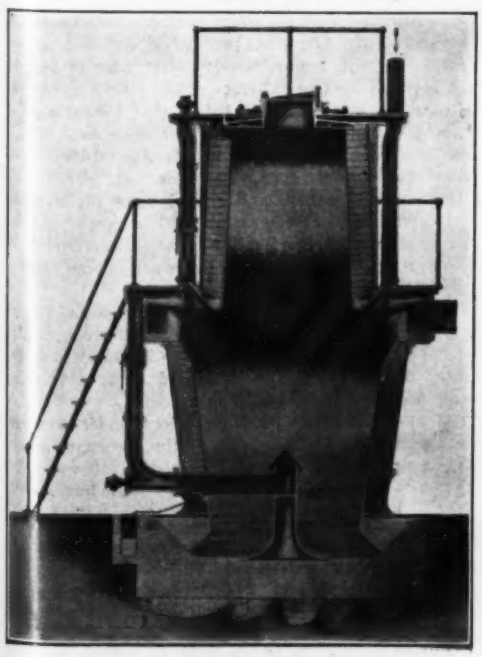


Fig. 10.—Double zone producer.

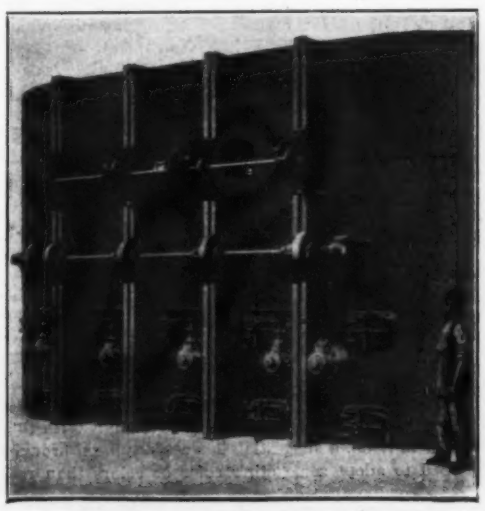


Fig. 12.—Front view of big producer.

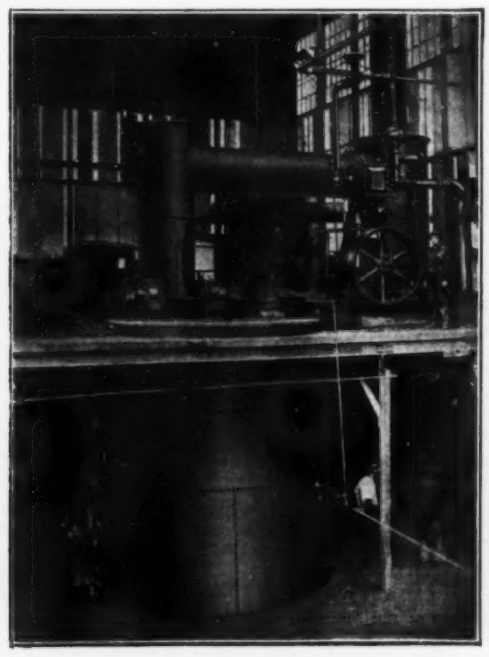


Fig. 11.—Largest single generator yet built.

engines. As a result, the bed is shot just as seldom as possible, sometimes not oftener than every six hours.

Another company uses a 4,000 horse-power plant of this type. This company requires about 2,000 horse-power for engine purposes, and the remainder of the gas for heating, tempering, annealing etc. In consequence, they shoot the bed just as often as possible, heating it up as rapidly as they can and then shooting it.

Tar can be satisfactorily converted into gas under the proper operating conditions. If, however, the temperature is not quite right, lamp black usually results.

Fig. 13.—Tar extractor for big producer on charging floor.

Fig. 14.—Charging floor of big producer, showing gas exhauster.

In the type of plant described above, as the ash accumulates between the coke bed and the green fuel bed, the plant is intermittent and must be shut down in order to recharge. The charging door may be opened and the coal charged directly into the producer, the whole operation being in full view of the operator.

Fig. 10 shows a type of producer with a double zone, in which are run two fuel beds, the object being to get rid of the tar. The coke which comes down through the upper zone becomes the main fuel for the lower zone.

A plant which was installed in the summer of 1913, and which illustrates the latest type of producer, is shown in Fig. 11. This producer is installed in Illinois, and is the largest single generator producer in the world. The producer proper is of simple construction and is made out of sheet steel and channels. It has semi-cylindrical ends and flat sides, as shown in Fig. 12. The capacity of the plant is 40 tons of Illinois bituminous coal per 24 hours. The producer is equipped with what is known as the "Smith Type F Tar Extractor," having a capacity of 250,000 cubic feet per hour. This is not a centrifugal extractor, but consists of a double-tee arrangement; it has no moving parts and requires no water. The tar extractor in position on the charging floor is shown in Fig. 13. In this figure may also be seen the gas exhauster.

Fig. 14 is another view of the charging floor, showing the charging hoppers and the engine-driven gas pump.

Centralization will undoubtedly become one of the essential factors in producer gas work, and even now railroads are considering the question of installing large central plants at the coal mines and utilizing the fuel there. Many important advantages are to be secured by the installation of such large plants, not the least of which is the practical elimination of the smoke nuisance.

This alone is an important matter for consideration, especially in the case of plants located in large cities, for municipal regulations for the suppression of smoke are constantly becoming stricter.

Belgium's War Dogs

CONVINCING testimony to the usefulness of the dog has been supplied by the campaign in Belgium, our brave little allies employing large numbers for pulling machine guns and accompanying sentries on nocturnal duties. Curiously enough, this form of traction has only been adopted within the last year or two, and only fifteen months ago a Belgian Service paper wrote approvingly of the experiment, pointing out that, in addition to being docile and competent, the animals had become great favorites among the soldiers.

Among their advantages it was mentioned that they move silently, without apparent effort, over the roughest country, and that they are practically invisible a few hundred yards away. With striking prescience, the writer observed that the military Great Danes would be called upon to play a particularly effective and glorious part, little realizing probably how soon his words would become true. According to correspondents, the dogs have more than justified themselves. It is doubtful if their capacity is fully realized by those who have not studied the question. Over bad ice Arctic explorers do not hesitate to allot a weight of from 100 pounds to 150 pounds to each member of the team.

As it happens, the military authorities in Belgium must have found plenty of material ready to hand, since dogs are of considerable economic value in that country. Something like 175,000 are in constant use for drawing the small carts which to us are such a novel and conspicuous feature of life in Belgium. Butchers, bakers, milk vendors, small farmers—all have their dog teams. An early seventeenth century painting proves that the custom existed in those days, but it was not more than twelve years ago that a society came into being, the object of which was to encourage the breeding of a more powerful animal, to ameliorate the condition of those employed, and to replace those that die, free of charge to all owners who contribute the very moderate insurance premium of two francs annually.

Economists having estimated the daily worth of each dog variously from sixpence to a franc, it is easy to see how materially this canine army contributes to the wealth of the nation. The National Federation for the Breeding of Draught Dogs has a membership of over 2,000, and its operations are under the control of nine syndicates—one for each province. The Belgian and Provincial governments, recognizing the importance of the work, contribute annual subsidies to the Federation.

In that sad exodus from Antwerp it was interesting to read that the brave dogs were doing their part, dragging the effects of their hapless owners or easing the journey of children or old people.—*The London Daily Telegraph.*

Red as a Danger Indication*

The Value of Various Colors for Signaling Purposes

By William Churchill

RED is pre-eminently the color which, throughout nature, attracts attention, excites curiosity, and arouses to action. Nature does not make lavish use of the bright reds and scarlets in laying out her color scheme, but when she does employ those hues it is generally to bring about definite action.

Most naturally, therefore, when it became necessary in the development of railroad service to select a symbol of danger, red was the color chosen. In the course of time, green was adopted either for a clear or for a cautionary indication, and within the past twenty-five years yellow, blue, purple, and lunar white have been added to the list of recognized signal colors. In semaphore signals, European practice is confined mainly to the use of red and green. Here in America, where automatic signaling is far more extensively developed than abroad, the general practice ten years ago was red for stop, green for caution, white for clear. Of recent years most roads have adopted yellow in place of green for caution and made green the clear indication.

Whatever the system of signal indications, it is obvious that there is no place in active railroad service for any man with defective color sense or even with impaired vision, unless full correction can be made with suitable glasses.

Similar remarks apply to the marine service, but at sea the established system of signal lights makes less demand on the color sense than is the case in the railroad service.

The past ten years has witnessed a great increase in the use of red lights by night and red signs by day for a variety of warning indications entirely outside the railroad and marine service. Custom long ago fixed on the red lantern as the proper warning indication at an open ditch or other obstruction in a highway or public street. When automobiles began to multiply, it was quite natural that the red tail-light should make its appearance and soon be made obligatory by law. More recently still, public demand for better fire protection in hotels, theaters, and public halls has given rise to the habit of marking all exits by red lights; and now the movement for "Safety First," spreading from the railroads to industrial plants, has led to the widespread introduction of red signs or lights not merely for exits, but also to indicate dangerous parts of machinery, dangerous localities, high-power transmission lines, and the like.

This rapid increase in the general use of red as a cautionary indication obviously gives rise to the question as to what we are going to do to protect the color-blind individual for whom the red signs and red lights may be ineffective. According to the usually accepted statistics, about 4 per cent of all males and 1 per cent of all females are more or less color-blind, and in the great majority of cases red, or red and green, are the colors affected. Ought not a careful investigation be made to determine whether the ordinary red light or red sign is recognized as a danger signal by those afflicted with red-blindness? If not, can some special provision be made to cover all such cases as well as adapted to individuals with normal eyesight? With this thought in mind, a suggestion has recently been brought forward to adopt some other color or colors than red, e. g., a combination of yellow and blue, as a warning sign in industrial plants. The topic is surely a pertinent one, deserving of careful consideration, and should not be answered without much definite evidence, which seems to be lacking at present.

It is estimated that the solar spectrum includes about one hundred and fifty hues perceptibly different to the average eye with approximately thirty hues of purple lying between the two extremes of the visible spectrum. For signaling purposes it is obvious that a color should be as far removed from white or so-called "white lights" as possible; in other words, should have the highest possible degree of "saturation," or "purity," as it is frequently called, and should have the highest photometric intensity compatible with a proper degree of saturation. Furthermore, the colors selected must be sufficiently unlike in hue to leave little or no chance of possible confusion.

The Railway Signal Association specification recognizes six signal colors: red, yellow, green, blue, purple, and "lunar white." Of this list blue is the least satisfactory for reasons to be mentioned later, and is no longer used except in special instances.

The effective range of these colors under average weather conditions when used with the customary semaphore lamp and lens is approximately as follows:

Color.	Effective range.	Approximate transmission coefficient for standard semaphore lamp (oil burner)
Red	3 to 3½ miles	0.20
Yellow	1 to 1½ miles	0.35
Green	2½ to 3 miles	0.17
Blue	½ to ¾ mile	0.03
Purple	½ to ¾ mile	0.03
Lunar white..	2 to 2½ miles	0.15

* *Transactions* of the Illuminating Engineering Society.

In actual service it is seldom necessary to see a signal more than 3,000 feet (914.40 meters), but a light of barely sufficient intensity to be visible that distance would never be feasible for an important indication. Volume of light is essential as well as correct hue, and it does not require very dense fog or smoke to cut the range of even a standard red signal down from three miles (4.82 kilometers) to a few hundred feet.

Time does not permit the writer to take up in detail the theory of color as it affects the selection of these six standard colors, nor to discuss the methods followed in laboratory study of the problem. Suffice to say that by repeated melts of all available glasses, spectroscopic analysis, photometric and service tests, the theoretical possibilities were narrowed down to six definite tints. Numerous service tests were absolutely essential since atmospheric absorption and reflection, which cannot be effectively simulated in a laboratory, produce certain definite changes in the appearance of all signal lights. All colors seen at a distance are shifted more or less in hue toward the red end of the spectrum. This effect is, of course, most apparent in fog, haze, or smoke; at times it is strong enough to make a dull green out of a blue light, a yellow out of a "white light," a red out of a yellow light.

A few remarks on each of the recognized signal colors may help to bring out some points of general interest.

Red.—To normal vision red is beyond all question the most effective color for a danger signal. It is quite true, of course, that the eye is far more sensitive to light in the middle of the spectrum than toward either extreme, but of much greater importance is the fact that as the apparent size of the source diminishes red never ceases to look red. Its chromatic and achromatic threshold are always the same. This is not strictly true of any other color, although a good signal green approaches close to such a requirement.

Red has the further advantage that the intensity of the light can be increased by the addition of a considerable proportion of reddish orange light (620-590$\mu\mu$) without a pronounced change of hue because the eye is not very sensitive to change of wave-length in that region. On this account red has the longest range of all signal colors. That advantage, coupled with the fact that so long as it is visible at all, regardless of distance, intensity, or atmosphere, a red light is always and unmistakably *red*, makes it the ideal color for a danger indication when color blindness can be disregarded.

Yellow.—Yellow at best is not an ideal signal color. Its chromatic threshold is much higher than its achromatic threshold; or in other words, it can be seen as a light of indistinct color much farther than it can be definitely recognized. This difficulty is, of course, greatly increased by the circumstance that most of the ordinary sources of illumination are more or less yellowish in predominant hue and hence liable to cause confusion. The yellow signal may be mistaken for a "neighborhood light" close to the right of way. Some reaction time experiments conducted by the author twelve years ago demonstrated quite conclusively that yellow required a longer time for recognition than red or green, and that yellow and white were frequently mistaken for each other.

The fact that atmospheric absorption may make a yellow signal appear reddish at times is unfortunate, but never a serious objection so long as red remains the danger indication. Experience on many railroads has proven during recent years that the red-yellow-green combination is distinctly preferable to the older combination—red-green-"white" provided standard colors are used throughout.

Green.—Green is the most effective signal color except red. It is usually somewhat below red in range, due in part to atmospheric absorption, but a bluish green (approximately 500 $\mu\mu$) gives very good results. Recently it has been found possible to increase the transmission of such a glass by 35 per cent over the present standard without any loss in distinctness of hue, and it is probable that this new modification will show results in range of visibility nearly equal to the present standard red.

Since red, yellow, and green are the three principal long range semaphore signal colors, it is important that all should have approximately the same intensity, so that no one color may overpower either of the others when displayed in more or less close proximity to it. But the sources of illumination generally used (oil or incandescent lamps) are far stronger in yellow light than in either red or green. This means, accordingly, that the transmission of the red and green glasses should be kept at a maximum, while the yellow can properly be somewhat reduced below the highest intensity possible to obtain.

Blue.—Blue and purple are short range indications because the proportion of blue and deep red contained in the light of the sources commonly employed is extremely small. Both these colors must, of necessity, transmit quite a proportion of bluish green light in order to secure even a moderate amount of percentage transmission and range. Blue light is so rapidly lost by atmospheric absorption and reflection that the color of the blue signal tends to become distinctly greenish with distance. On that account blue never gives a really effective indication and is now seldom used, having been largely supplanted by purple.

Purple.—In a standard purple signal glass, the proportion of bluish green light transmitted is offset by red from the extreme end of the spectrum. The result is a color verging on magenta and about equally distant on the color scale from both standard red and standard green. The chromatic aberration of the eye is strikingly apparent in viewing a purple lens at a distance of 100 feet (30.48 meters) or more. The light appears ordinarily as a purple spot with a halo of deep bluish light surrounding it. This effect is varied more or less by conditions of astigmatism, as is well known to ophthalmologists. Such a purple produces a signal indication which for distinctness compares rather favorably with the other colors. Unfortunately its use is restricted by the fact before mentioned, that its total transmission and range of visibility is low.

Lunar White.—While studying the problem of how to render the yellow signal more effective, the writer was led to the conclusion that a bluish white signal could be made useful as an additional indication and would, in some respects, be preferable to yellow. By means of a pale blue glass we are able to eliminate enough of the yellow in a kerosene flame or incandescent lamp to make the light appear almost white with a slight preponderance of blue. This new possibility was called "lunar white," and has come into use as a clear indication for switches on a number of roads. In actual service it has proven to be at least as distinctive a color as yellow and to possess longer chromatic range for most observers.

The established system of railroad signal colors briefly mentioned above is based on the assumption of normal color vision. But when red is used as a warning signal for the general public, the question naturally arises whether red-blind individuals are properly protected. It is reasonable to assume that about 4 per cent of all the drivers of automobiles and other vehicles are color-blind. Before the importance of eliminating color-blind men from railroad service was appreciated, it was morally certain that at times serious wrecks were caused by defective color sense. It is highly probable that at the present time some automobile accidents are due to the same cause, although definite evidence is very difficult to obtain. It is hardly to be expected that all automobile drivers could be compelled to pass a test for color vision. Neither is it fair to ignore the color-blind in establishing a standard warning indication for vehicle tail lights, highway obstructions, fire escapes, and similar purposes.

Should not a serious effort be made to determine by actual tests with a large number of color-blind subjects whether the present red signals furnish sufficient protection? It is reasonable to assume from what is known regarding the peculiarities of abnormal color vision that a red-blind individual will perceive the average red light as a yellow of some sort, and that the yellow in such case will be of low intensity. As the color exhibited tends toward orange, the hue is likely to become more distinct, and the intensity, of course, higher. A purple light probably appears blue to the red-blind subject, and is at times confused with green lights on that account. This is one of the frequent mistakes made by color-blind persons undergoing test. But either an orange-red or purple light presumably is much easier for the red-blind or red-green-blind to recognize than an ordinary red light. It would be a waste of time to speculate on this point, but a carefully conducted series of tests would soon bring some definite evidence to light.

If either a reddish orange or a purple proves to be distinctly better for abnormal color sense, a standard shade could easily be determined which would be entirely satisfactory for normal color vision. Incidentally there might be some advantage in utilizing a hue which would be somewhat different from the standard red of railway service. It is the constant effort in signaling practice to reduce the number of red lights visible along the right of way to a minimum, so that red may indicate only two possible conditions to the engineer's eye; a "high-signal" set at danger or a "tail light" at the rear of a train.

Parallel to the investigation respecting the perception of red lights by the color-blind, a study should be made of the best pigment color or colors to use for danger indications. It would seem desirable, in this connection, that a standard danger symbol be developed and made international, just as in the marine service all over the world green signifies a starboard light and red a port light. Such a symbol should be simple, but as distinctive as a red cross flag. Theoretically, a circular blue or orange band inclosing a red center would seem to fulfill all requirements. It would be more striking in appearance than any mere black and white sign and it would furnish a colored indication to all types of color vision except the very rare cases of total color blindness. Practically no instances are found where the color sense for both red and yellow or red and blue is lacking in the same subject.

Such a symbol and such standardization of practice concerning lights for danger indications in public places or industrial plants might render some real service in the cause of "Safety First" and would certainly eliminate one possible cause of unnecessary accidents.

Ben Franklin Vindicated*

THE decline in popularity of lightning rods, following the pernicious activity of rascally agents, left a stain on the scientific reputation of the great and wise Ben Franklin, who developed this protection against thunder bolts. Scientists have stoutly defended the value of such equipment, if well put up, but, nevertheless, practical men, often speaking from bitter experience, have maintained continuously for generations that the rods have proved worse than useless.

Two valiant defenders of the faith, Profs. J. B. Reynolds and W. H. Day, of the Ontario Agricultural College, not contented with the inconclusive deadlock of theory and claimed fact, set out to find the truth—in practicable demonstrable form. For ten years, first one and then the other industriously collected all possible information about buildings reported struck by lightning in Ontario. At the end of this time (1910), they had data on 599 buildings struck by lightning. Of this number struck, 317 or 53.6 per cent, were burned, but only 18 of the buildings struck, or 3 per cent, had rods and only three of these, or 16.6 per cent, of the protected buildings were burned. Having these interesting but incomplete figures, the investigators desired to know further the number and experience with unrodded buildings in the province, so that they might complete their case—reasoning that if rods neither prevented nor induced strokes the ratio of damaged to undamaged structures in the unprotected risks would be of the same order of magnitude as in the rodded.

Great difficulty was found in securing the desired data. Eventually, however, the provincial mutual insurance companies were interested in the studies and reports covering about a fourth of the province were secured after some delay. These showed that 21 per cent of insured farm buildings were rodded and that of all those struck only 1½ per cent were rodded. Of 7,000 unprotected buildings, 37 were struck; out of 7,000 protected ones only two were struck. Therefore, 35 were saved out of 37 expected to be struck, or a probable protection of 94.5 per cent and that with uninspected rod construction.

Prof. Day visited Iowa and Michigan to inspect the insurance reports and methods of protection there. In Iowa, he found that the total claims paid for lightning damage in eight years amounted to $4,464 on rodded buildings and $341,065 on unprotected ones. Apparently then, for each dollar paid on rodded risks $76 was paid on unrodded. The rods were not inspected and some of the losses probably were due to poor construction. Even so, the protection shown was 98.7 per cent. In Michigan, one mutual company insuring only rodded and inspected buildings, in four years paid $32 claims on $55,172,075 risk. Another mutual company taking both protected and ordinary risks paid $32,269 in claims on a total of $59,567,272 in the same period. The loss was practically all on unprotected buildings aggregating $45,753,818 in value of risks. Comparing the two companies, for each $1 damage on protected buildings there seemed to be paid $1,168 on unprotected ones—an obvious protection of 99.9 per cent. All this and more is set forth at length in a recent bulletin of the Ontario Department of Agriculture.

Regarding the technique of the rod construction so successfully employed in these states, it is of interest to know that, where knowledge was available, there appeared to have been used more or less of an approach to a cage of conductors about the building. The rods were fastened both close to and away from buildings but without insulators. Deeply buried ground plates and rods were found and where these groundings proved defective there invariably developed disaster.

The worthlessness of the old lightning rods, of course, was the fault of the loquacious fly-by-night agent who carelessly put up his cheap affairs, gathered his money and disappeared, leaving disaster and ruin for many a farmer on the approach of the first heavy electrical storm. A deliberate campaign to discredit the great American philosopher and patriot could not have worked as well. It is a source of much satisfaction to see definite figures which substantiate the soundness of his scientific knowledge as well as that of a long line of later physicists.

*From the *Engineering News*.

The New York Fire Alarm System

A History of the Past and Plans for the Future

By Putnam A. Bates, Electrical Engineer, Chief of Bureau of Fire Alarm Telegraph of the City of New York

THE movement for an improved fire alarm system for the City of New York which the present administration has taken in hand, was started in December, 1904, when the insurance companies urged that a committee be appointed to investigate the situation and make a report of its findings.

In 1905, the New York Board of Fire Underwriters made a six months study of the problem and rendered a report condeming the present system as beyond repair. This investigation was limited to conditions on the island of Manhattan.

The following year the city itself took hold and in March, 1907, preliminary plans and specifications were prepared for a modern fire alarm system for the island of Manhattan, but there was no attempt to engage in the work of reconstruction until about four years later. Small appropriations were set aside for this much needed improvement as early as 1903, but these funds were largely diverted to keeping the old system in operation, and in the ten years which followed the money set aside for installing a new fire alarm system in all boroughs has aggregated the substantial sum of $1,609,000. That progress toward reconstruction has not been accomplished is a matter reflecting little credit, being born of no definite plan of procedure.

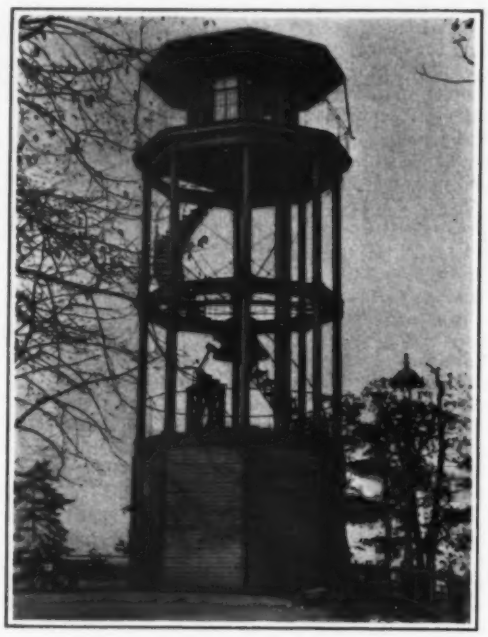
The preliminary plans required the building of the new system before the abandonment of the old. This course should have been followed, but unfortunately it was not, and the new contracts that have been entered into aggregate too small an amount for economic handling, and constitute patch work at high rate of cost.

I see no valid reason why the practical installation of a fire alarm system for a large city should follow a different course than that usual in important engineering operations of other character. There is a certain economic relation that must be maintained between the supervising staff, or overhead cost, and the scope of the work itself. Proper efficiency cannot result where this fact is disregarded, and my efforts during the past six months have been devoted largely to accelerating the work of bringing outstanding contracts to a close and to raising the standard of the bureau staff to a point where greater work can be handled with increasing ease.

The agreement by the city with the Empire City Subway Company in 1891 makes it mandatory upon that company to provide the city with such ducts as may be needed for the fire alarm wires in all streets and avenues where subways exist, or where there may be a demand for subways; thus the city will be able to install the modern fire alarm system without constructing subways, which offers an advantage in time as well as in cost. The saving will extend in like manner to the Bronx, Brooklyn, Queens and throughout the built up portions of Richmond, as it is proposed to pursue the same general plan in all boroughs.

In taking up this problem, my first inclination was to learn the disposition made of outstanding appropriations, and the extent of new work that had been undertaken, which I found to consist of the following: A new central station building for each of the three larger boroughs, Manhattan, Brooklyn and the Bronx; underground service cables for connection to 138 street boxes in Manhattan; similar underground installation connecting 199 boxes in Brooklyn; an important underground feeder line reaching to southwest Brooklyn; bridge cable connecting Brooklyn with Manhattan; underground service cables for connection to 119 boxes in the Bronx; a similar underground installation connecting 8 street boxes in Queens; a supply of 2,000 alarm post bases; a supply of 300 cast iron manhole frames, and concentrating subways leading to the new Manhattan Central Office building and the similar building in the Bronx respectively.

These contracts aggregate about one-third of the total appropriations made thus far, and all of them were in an unfinished state with the exception of smaller items, representing a total of about 5 per cent. The unencumbered balances were about equal to the aggregate of the contracts placed, leaving a remainder of about one-third of the total appropriations diverted to other uses, principally that of maintaining the old system.



This old fire department bell tower, still standing on a high point in Mt. Morris Park, Borough of Manhattan, is the last of twelve look-out stations located at places of advantage, such as the cupola of City Hall, and the public markets.

This method of sending alarms of fire New York city depended upon until 1870, when the system now in use was installed.

Before describing the present day conditions and plans I will refer to the early history of fire alarm telegraphy in New York City, from the beginning in the year 1865.

At that time the fire alarm plant consisted of twelve bell towers, or look-out stations, located at points of advantage, and the mode of operation was to watch for smoke or other indications of fire with a telescope and to signal by means of the Morse telegraph, directly to the central office. The signal was then communicated to the department by striking the bells at the twelve bell towers.

The central office at the City Hall was the terminus of four lines of wire connecting the Post Office, Essex Market, Union Market, MacDougal, Jefferson and 51st Street towers. In each of these stations was a main circuit magnet and bell, and a circuit breaking key. The signals indicating the districts in which the fire was located were sounded on these bells, with the numerical designation of the station giving the alarm.

The city was divided in eight districts, the first two being that part of the city above a line drawn through 22nd Street. In these districts the signals were struck on the fire bells by the bell ringers in the towers, and were the only guide the firemen had in locating a fire.

From the central office eleven lines radiated connecting the engine, hose and hook and ladder company houses below 14th Street, which, with the instruments placed in these houses, was known as the Robinson telegraph.

This primitive system was soon found inadequate, and in 1870 a complete new installation was made at a cost of $450,000, and including about 578 street alarm stations. The records of the department show that few difficulties were experienced for a period of ten years, in fact many decided improvements in its working were effected, and this installation is the basis of the present day fire alarm telegraph plant in the Borough of Manhattan.

We thus come to the year of 1881, and it is interesting to turn to the records following the storms of that year. The description of the damage to the fire alarm system that winter so closely resembles the conditions reported in March last, that I quote the exact phraseology as I find it in the year book of that time, as follows: "An extraordinary sleet storm occurred on January 31st rendering the fire alarm telegraph so nearly inoperative that at one time there were but six of the 578 street alarm boxes in communication with the central office, at headquarters, in consequence of the prostration of the wires. Since it became apparent that the telegraph would be endangered, street patrols were established in each company district for the discovery of fires; the communication of alarms to the companies required each response by mounted details; the discontinuance of all leaves of absence; ringing of the tower bells for fires and details of men from the upper to the lower part of the city."

This serious situation was followed by the passing of resolutions and much public comment, but history repeats itself and the public soon quiets down after a critical moment is past. It therefore is not surprising to find that the storms of 1888 and again of 1914 completely demolished the fire telegraph system not in Manhattan alone but in Brooklyn, Queens, the Bronx and Richmond.

It is a matter of experience that whenever serious trouble occurs, affecting many of the line wires, the alarm load goes up correspondingly. The fact makes the reliability of the alarm system doubly essential as it is during high winds, sleet and snow storms, or other circumstances likely to threaten conflagration that efficient operation is most needed.

Through sheer good fortune New York City has passed through three sensational moments when it would seem that only the protection of a higher power has saved it from great disaster.

In a large city like New York the operation of the fire alarm is accomplished manually. Many attempts have been made in the past to devise means whereby the full operation might be performed automatically, but so far none has been evolved which is feasible and safe for a large city. In the present installation there are two distinct classes of circuits: box circuits and engine house circuits. All street fire alarm boxes in the Greater City are operated on "closed circuit," in other words,

After the snow storms of March 1st and 2nd, 1914, mile after mile of wire and hundreds of poles lay upon the streets of the outlying boroughs.

The conditions were at their worst in the Bronx, Brooklyn, and Richmond where electric light, telephone, telegraph and fire alarm wires were tangled together in a hopeless mass. With the present "overhead" fire alarm plant, New York city is in danger of serious conflagration should a fire break out at a time when the telegraph circuits are inoperative.

current is constantly flowing and any interruption in this flow may be detected at once at the central office. In that way the operators at all times know the condition of their lines.

When a street box is "pulled" the clock work mechanism in the box rotates a disk having notches cut in its periphery, which causes a switch to open and close the circuit periodically according to a prearranged order or time interval. This operation causes a certain number of taps on a bell in the central office, and a corresponding number of dots on a register tape, which spell out the number of the box. Upon receipt of the signal the operator transmits it to the engine companies.

Manifestly the central office must be surrounded by every possible safeguard, as its security is vital to the success of the entire fire extinguishing forces. It was strongly emphasized in the preliminary plans that the central office of the fire alarm telegraph system should have the maximum degree of protection against hazards of every nature, and in order that it should occupy a place which would form an economic and safe center, it was recommended that the central office building for Manhattan should be located on Transverse Road No. 1 running through the southern section of Central Park, which is a sunken road, concealed from view; but the final disposition of the matter as the result of recommendations by the Department of Parks was to locate this building on Transverse Road No. 2. The fact that the building is in the park is an unquestioned advantage, but unfortunately this particular location is surrounded by hazards which will necessitate additional work to insure safety. It is obvious that the presence of a large body of water, such as now exists in the lower reservoir, approximately 150 feet north of the site selected for the Manhattan central office, is a hazard, as are also the presence of a 20 inch and 48 inch water main in the road immediately in front of the building and the gas mains which lie in the same street.

In Brooklyn and the Bronx the sites selected for the new central office buildings, were in public parks in each instance, but the hazardous conditions mentioned in reference to the Manhattan central office are not present.

In planning the locations for the street boxes, the general rule now followed is that a box will be found at every other corner. In some instances exceptions are necessary, but the tendency is to increase, rather than diminish, the frequency at which the boxes occur.

The fire alarm service to schools and city buildings must necessarily be treated as additional to the street box service, but in a similar manner.

It is the purpose of the present administration to place all new wires which form the fire alarm circuits underground as far as practicable, and the specifications adopted for these cables require that they should be composed of solid conductors of soft copper of a size corresponding to No. 16 B. & S. gauge. Each conductor shall be tinned, and insulated with a high grade vulcanized rubber compound, the thickness of the insulating wall being not less than 3/64 of an inch and 30 per cent fine Para rubber compound with mineral base will be required.

The central office equipment in the case of the three boroughs in which new buildings have been erected is yet to be designed.

The new installation will be so planned as to enable it to operate in accordance with the present routine of the companies and officers of the department, and to allow for sufficient flexibility so as to be readily adaptable to any changes that may in future be considered necessary.

The fire alarm equipment in the outlying boroughs is a matter of no small importance, especially in consequence of the enormous increase in the number of wires comprising the electrical systems, the majority of which are still carried overhead on pole lines. The interference of electric light wires with those of the fire alarm telegraph is a source of constant menace. In a number of instances on record, street alarm box circuits have for hours been rendered useless through the destruction of the electrical mechanism of the boxes due to the crossing of conductors with wires carrying heavy currents of high potential. The danger of such interference need hardly be stated, though it will bear reiteration to say that the first seconds after the outbreak of a fire are of incalculable importance to the fire department, and anything tending to deprive it of the quickest method of getting such notice may carry with it most disastrous and ruinous consequences.

The only manner in which this constant source of difficulty may permanently be eliminated is by the laying of all conductors underground. This is the chief problem incidental to the completion of modernizing New York City's fire alarm plant, and measures must be taken to proceed with the extension of the underground system in such manner as will enable the work to progress under a uniform plan and not by piecemeal.

The transferring of the circuits to the subways, which was begun on the island of Manhattan as early as 1888, has to some extent been continued each year, but at entirely too slow a rate. The work has been prosecuted under many disadvantages, however, and the appropriations have been adequate only for small extensions. The work has also been delayed through the impractical procedure of attempting to make these extensions before a complete plan for the entire undertaking had been prepared.

In past years, the city has availed itself of the opportunity offered to attach its wires and cables to the elevated railroad structure and while this method served its purpose to a large degree, it was at the best a makeshift. It was regarded at the time as the best and cheapest method of providing a support for cables, and at the outset the cost of maintenance was small, due to their being less liable to mechanical damage, and the ease with which troubles could be found and removed. This, however, was when the elevated trains were operated by steam, and the third rail carrying electric current of high potential was not present. The dangers from the power current, and the excessive deterioration which has taken place in these cables, has caused this installation to be regarded as one of the most unreliable elements in the fire alarm system at the present time.

With the consolidation of the five boroughs into the greater city, the problems and difficulties of a better fire alarm service became greatly increased, as the outlying boroughs had merely a semblance of a fire alarm system, and this of a most inadequate character.

It is interesting to note the manner in which the fire alarm system in the Borough of the Bronx came into being. When the last attempt was made to modernize the fire alarm system in New York City in the year 1870, covering at that time the island of Manhattan, there were 700 boxes installed upon 50 circuits, and subsequently these circuits were extended to the present Borough of the Bronx, and some 300 boxes added thereto. Since then from time to time new boxes have been added until these original circuits were carrying a total of 1,350 alarm boxes, with the result that some of the circuits were too great in length, and all were so overloaded as to militate against their efficient operation. This condition has been relieved in a measure from time to time through the construction of additional lines, but the bad planning of the original installation is evidenced by unfavorable conditions which are still in existence. The Borough of Brooklyn has suffered to an even greater extent through this same difficulty, and is in a serious condition in this respect at the present time. In like manner the circuits in the Borough of Queens and Richmond are carried for great distances, and serve many more boxes than would be considered proper with a modern installation.

The entire extent of the circuit mileage including both the underground and overhead wires aggregate in the five boroughs between 3,500 and 4,000 miles, and it will be seen from this that the more substantial the method of installing these conductors, the less will be the cost to maintain them.

The problem, therefore, is to create as promptly as possible an adequate cable plant that will provide for such future growth as may be necessary and which will efficiently operate under present service requirements. These cables when installed in the existing underground conduits will provide the most important single item of a complete modern system. The system in the various boroughs is at the present time so antiquated as to be virtually a disgrace for such a municipality as New York City to own. Some of the original apparatus installed from 1865 to 1870 is still in service, and it is safe to say that with the exception of the central office of the Borough of Queens, and similar installation in the Borough of Richmond, the entire telegraph system of the greater city is obsolete.

The line plant in the various boroughs is inadequate and unsatisfactory. Seventy-five per cent of the area of Manhattan relies for protection upon two cables on the elevated structure, which are exposed to constant danger of destruction. In the other boroughs, overhead construction is almost exclusively used, no uniform plan or system in routing of the various lines has up to this time been adopted, and as a consequence there is an intricate net work of interlaced circuits difficult of supervision and maintenance. The lack of system in the planning of the cable plant in the various boroughs is probably responsible for not only more than one-half of the troubles encountered, but also for the maintenance of fifty per cent more wire than would be necessary, if the most direct routes had been followed.

A brief statement of the scope of the new plans as they are now being prepared undoubtedly will be of interest, and I will include sufficient details to give a practical idea of the character and extent of the equipment proposed for each borough.

MANHATTAN

The plan of street box locations provides an installation of approximately 1,650 fire alarm box posts, so spaced that a person will not have to travel more than 400 feet from any point to the nearest fire alarm box, and in many cases, especially below Fulton Street, this distance will be much less. It is proposed that all of the feeder and distribution wires shall be in cables laid underground, which insures the greatest protection against interruption as well as maximum life.

THE BRONX

The new work proposed for this borough will be of such character as to constitute a ten year improvement. The majority of the feeders will consist of cables entirely underground, as well as a large proportion of the distribution circuits owing to the availability of conduits which have been or will be provided by the commercial subway companies.

BROOKLYN

It is proposed to provide a permanent installation for one-third of this borough, as the vast extent of the borough in itself makes the planning of a modern fire alarm installation a very difficult and expensive problem

Fire Alarm Telegraph Bureau Central Office at Fire Headquarters, Borough of Manhattan.

Showing the alarm box circuit switchboard and receiving instruments. From twelve o'clock midnight until eight in the morning two fire telegraph operators watch over the lives and property on Manhattan Island, and the protection of the borough from the spread of fire depends largely upon the alertness and accuracy of these two individuals.

unless taken up in sub-divisions, and the problem for each solved according to local conditions, owing to the relatively undeveloped character of the property on one side of the borough as against that of the other. Along the water front from Newtown Creek to and including Coney Island, valuable property and many lives are at stake to-day through inadequate fire alarm protection, and in this important section it is contemplated to install, as promptly as appropriations can be obtained, a modern system. This installation will be extended to include practically one-third of the entire area of the borough, leaving the remaining portion to be treated after the first undertaking is well under way.

RICHMOND AND QUEENS

These boroughs present quite an undeveloped aspect when compared with the other boroughs and, except for those extensions which are needed to rectify unsafe conditions, it is not my intention to prepare plans at this time for extensive improvements. However, a considerable number of additional boxes will be installed and the circuits in the well built up sections are to be laid underground in cables of sufficient capacity for the growing needs of the territory served for many years.

The cost of installing the complete fire alarm system in all boroughs, I have estimated at $5,000,000. However, to carry out the plan on the basis of the recommendations I have recently submitted to the Fire Commissioner would involve an immediate expenditure of approximately $2,000,000, and this installation when completed would result in a material reduction in the cost of maintenance, and would vastly increase the protection to life and property through the improved reliability of the fire alarm service.

Stereoscopic Drawing*

A Training for Accurate Workmanship

By Charles E. Benham

If a test were required for the accurate workmanship of a student in mechanical drawing, no better one could be devised than to set him the task of representing an object in perspective as seen by the right and left eye respectively. The two drawings, when placed in the stereoscope, should show a perfect effect of solidity; but

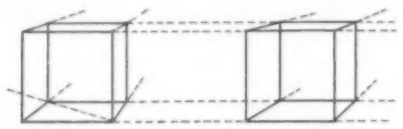


Fig. 1.—Showing method of stereoscopic drawing.
The dotted lines represent the penciled construction lines.

the slightest deviation from exactness in either drawing would manifest itself in the stereoscope very distinctly, and there are few amateurs whose first attempt would not be a failure.

By care and practice, however, very good results may be obtained; and for many scientific diagrams, in which a three-dimensional representation is necessary, stereograms are very useful, and may be substituted with ad-

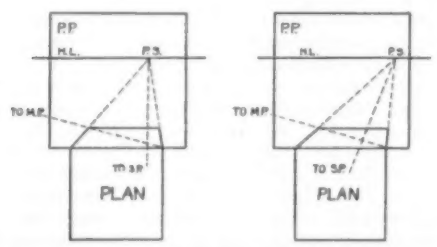


Fig. 2.—The left-hand figure shows the ordinary perspective paper as figured in the text books.
How the diagram should be thought of by the student is revealed by the stereoscopic view.

vantage for clumsy models. As examples may be mentioned the forms of crystals, the imaginary planes that have to be explained to students of perspective, the diagrams required to illustrate the polarization of light, reflection, refraction, and other branches of optics, or, for speculative students, the mysteries of the hypercube.

A difficulty occurs in the limited field allowed by the refracting stereoscope. This necessitates rather small drawing, and, as the lenses of the instrument magnify, the smallest errors are unpleasantly enlarged. More-

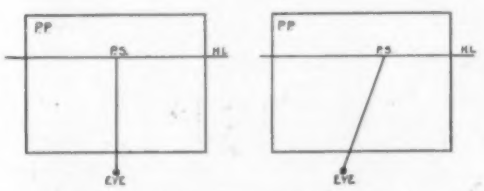


Fig. 3.—Another perspective diagram.
Showing the relative positions in which the horizon line picture plane and station point ought to be regarded.

over, to avoid distortion, it is desirable that a perspective drawing should come within a horizontal angle of sixty degrees, and a vertical angle of not more than forty-five degrees, which, again, seriously limits the scope of the drawing.

It would be better undoubtedly to construct a special stereoscope with plane prisms allowing of an extensive distant unmagnified field; and, though such an instrument would have to be rather a bulky affair, it would answer the purpose much better for the exhibition of hand-work, and would enable the draughtsman to make his drawings on a less diminutive scale.

Another way is to draw large and reduce by photography to stereoscopic dimensions. With intricate diagrams this is much the best way, and very beautiful results can be produced.

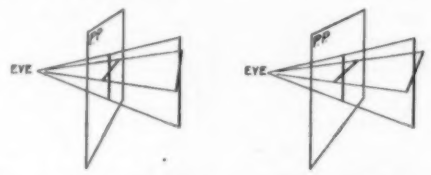


Fig. 4.—Diagram showing how the image of an object is formed on the picture plane by lines drawn from all points of the object to the eye.

The red-and-green-spectacle method of stereoscopic representation is another way out of the difficulty. The two drawings, which may then be of any size, are drawn (almost superposed), the one in green ink, the other in red. Two gelatine films, stained respectively with the same red and green inks, are used for the spectacles, and the figure is seen like a solid wire model in front of the paper. The process, however, is imperfect. With the red gelatine complete extinction of the red lines is easily obtained, but the green lines always show faintly through

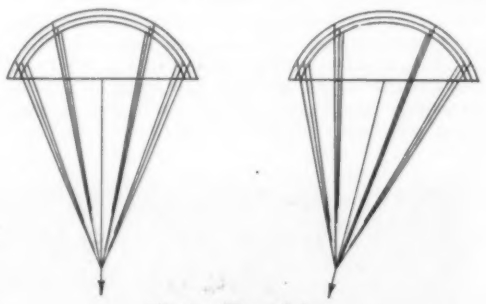


Fig. 5.—The rainbow.
A line is shown, which, if produced, would pass through the spectator to the sun. It will be seen in the stereoscope how the refracted rays form an angle with this line on all sides. The original of this diagram is in colors, making it all the more instructive.

the green film, unless the dye is so dense as to obscure vision, or unless the color-screen is a liquid one, which is obviously inconvenient, though extremely perfect in its effects.

The actual method for drawing for the stereoscope is very simple, extreme accuracy being the main essential of success.

Bearing in mind the prescribed limitations of size and angle of vision to which reference has already been

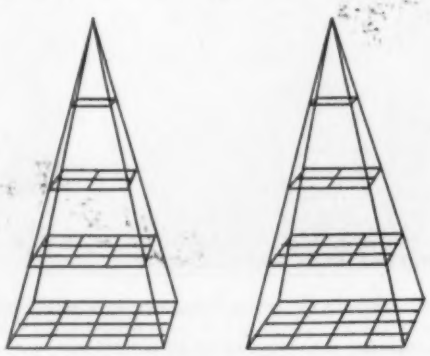


Fig. 6.—The law of inverse squares.

made, the object is first drawn in perspective in the ordinary way. Take, as a simple illustration, a cube. The perspective representation is drawn as on the left in Fig. 1. Pencil lines are drawn horizontally from each determining point of the figure, as shown by the dotted lines in the illustration. These are guides for the posi-

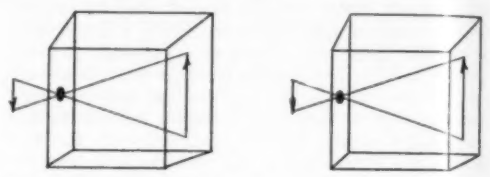


Fig. 7.—The pinhole camera, illustrating the formation of the inverted image.

tion of the corresponding points in the right-hand figure. By this means no measuring point is required for the second drawing, as it is obvious that all these corresponding points must lie in a horizontal line with those of the first figure. The right-hand drawing is placed two and a half inches to the right on the picture-plane, the point of sight being moved an additional half-inch, that is, three inches to the right of the original point of sight.

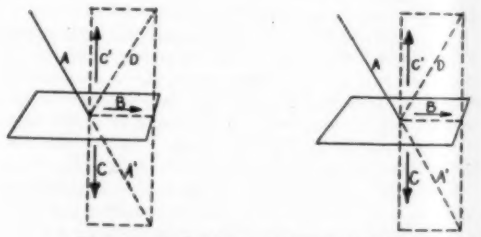


Fig. 8.—Reflection of elastic bodies.
Diagram showing how the principle of the parallelogram of forces explains the angle of reflection.

The limits of stereoscopic separation range between two and a half inches and nearly three inches, so that if the vanishing points are separated by three inches, and the nearest points of the drawing by two and a half inches, the whole picture will be seen comfortably without strain. Even a separation of three inches is too wide for some people; but, as the vanishing points themselves do not figure in the finished drawing, it is safe to give

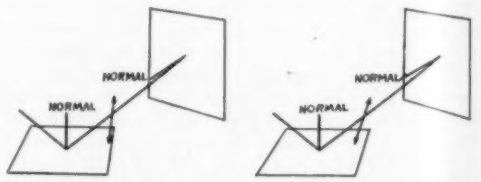


Fig. 9.—Polarized ray reflected from a horizontal plate, but unreflected from a vertical plate when incident upon it at the same angle with the normal, viz., 54½ degrees.

them that amount of separation; for probably no part of the actual drawings will be more than about two and three-quarter inches apart.

It will be seen from Fig. 1 that by drawing the receding lines to the new vanishing point for the right-hand figure they will be measured off by the horizontal lines. If an angular or oblique vanishing point enters into the left-hand drawing, it must similarly be moved on three inches for the right-hand drawing.

Accuracy is best insured by pricking the paper with a fine needle at each determining point that is established, and then drawing to these needle-pricks.

* From *Knowledge*.

Having completed the drawing in pencil, test it, without removing the construction lines, by examination in the stereoscope. If it is true, the whole may then be carefully ruled in with ink. If the stereoscope reveals faults, the lines should be carefully revised and corrected in pencil until they correspond in the two drawings.

It is a good plan, instead of inking over the original, to mount it, when all the determining points are quite accurately placed, over a piece of blank paper on a drawing board, and with a fine needle, mounted in a handle, prick through all the holes, so as to stencil the whole key to the diagram on the lower sheet. Two sheets or more at a time may thus be stenciled, taking great care that the needle-holes are made absolutely vertically. Join up the points on the stencils in ink with a ruling pen, and each will give a complete stereogram.

If the work of preparing the drawings is considered too tedious and troublesome, the services of a professional draughtsman may be engaged; and, by providing him with plan and elevation, and such instructions as are given above, he will produce results much more perfect than those to which the unpractised amateur can attain without repeated trials and failures. Figs. 5-8 accompanying this article were drawn in this way and are good examples of professional accuracy.

Figs. 2-4 are specimens of an instructive series illustrating principles of perspective.

Fig. 5 represents the principle of the rainbow, and makes it clear how the refracted rays from all parts of any color band all form the same angle with a line from the sun to the spectator; a fact which is often puzzling to students.

Figs. 6 and 7 represent respectively the law of inverse squares and the principle of the pinhole camera.

Fig. 8 is a diagram to illustrate the laws of reflection of elastic bodies.

Figs. 9 and 10 are from a series of polarization diagrams, and show special cases in which the stereoscopic method takes the place of models in a satisfactory manner.

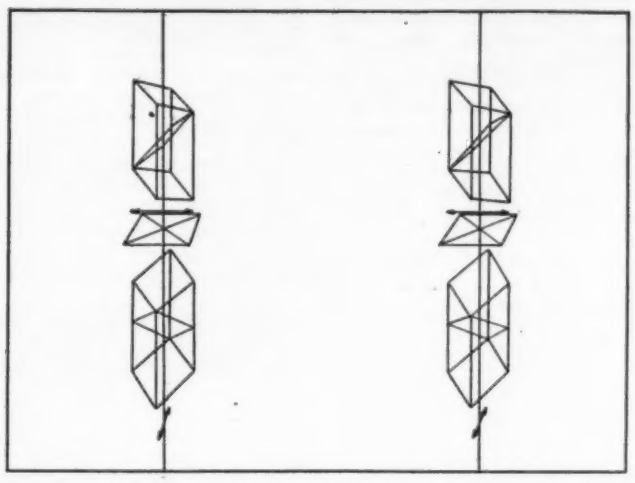


Fig. 10.—Diagram showing the change of plane effected in a ray in passing through a nicol prism; secondly, through a film of selenite; and, lastly, through a second nicol.

An Historical Sketch of the Gas Engine

Tracing the Origin and Development of Different Types

By John Hays Hammond, Jr.

To-day the field of the internal combustion engine is being viewed in its prospect; in a retrospect of the evolution of the gas engine we can pay a slight tribute to those pioneers whose efforts have benefited humanity at large.

From the year 1678 A. D. when many unsuccessful attempts were made to utilize the expansive energy of gunpowder until the present day, the progress toward the perfection of the internal combustion engine has been a uniform one. The main factor in the adoption of any type of prime mover has always been the question of economy, and in this respect the internal combustion engine ranks supreme, both in thermal efficiency, general simplicity and compactness of structure.

The pioneers in the field of gas engineering were numerous, each to a certain extent adding to the general knowledge of its phenomena, but there are comparatively few to whom may be credited any radical changes. Among the illustrious names connected with the experimental work which has brought the gas engine to its present high state of perfection, are those of Beau de Rochas, Million, Daimler, and Otto, all contributors of invaluable information to the art.

It is, however, to De Rochas, a French engineer, whose knowledge in the theoretical conditions of the gas engine far exceed his time, that we owe the theory upon which our modern units are built and operated. He was the first to realize the inestimable advantages of high revolutionary speeds, high compression, and the consequent high thermal efficiency which is now generally recognized as the main factor of economy. It is rather curious that though cognizant of these facts, Beau de Rochas never cared to practically demonstrate his views; it can, however, be accounted for, for De Rochas was much of the theorist and but little of the practical engineer, and he left it for others to make concrete his ideas. It was not until fifteen years after enumerating his principles (1877) that practice adopted his revolutionary ideas. Besides predicting the advent of the four-cycle motor, De Rochas advocated combustion by compression, which principle we find involved in the modern Diesel engine.

Occupying the same position in practical inventions that De Rochas occupied in the theoretical, ranks Otto. This German engineer was the inventor of the first practical four-cycle engine. Although invented in 1876, the four-stroke engine is still in the market, outnumbering by a vast majority all other existing types of motors.

In opposition to the four-cycle or Otto cycle engines, we find the Day or two-stroke motor to be theoretically possessed of many valuable qualities. Though considered with respect to their relative practical merits, it is hardly necessary to mention the fact that the Otto cycle is for medium power units much more efficient, for its preponderance over two-cycle motors on the market testifies to this. To the layman, however, it would seem that the two-cycle engine would be far the most preferable of the two types, for with twice the number of explosions and the same weight combined with greater simplicity, we should expect far more efficient service. In matter of fact, however, we find that instead of giving twice the horse-power for a given bulk and weight of the four-cycle engine, the two-cycle engine when run at any speed over 800 revolutions per minute ceases to operate with reliability, for its necessary functions of inhaust and exhaust do not take place. Consequently, we find two-cycle units operating under conditions where the factor of speed is not a requisite for its efficient service. Special modifications as found in the Diesel type, however, allow the two-cycle principle to be very efficient in high power units.

At the present time there are two recognized classes of internal combustion engines, one the working or low speed engine, the other the high speed motor. As the working engine far antedates the modern motor, and in fact forms the basis from which the high speed motor was finally evolved, we may first consider its invention and gradual development.

The history of the working gas engine deals principally with the experimenting of English engineers, for they did more to further its progression than did the engineers of any other nationality. Due to the small quantity of natural fuel in the British Isles, the English engineers realized the great possibilities in the adoption of gas as a fuel, and concentrated their energies in the production of a serviceable, economical, reciprocating engine.

As far back as 1826, we find attempts to use the presence of a vacuum by the explosion of gas, as a medium to actuate a suitable mechanism.

In 1833 Wright obtained patents on an engine of the double acting type, which was operated by the alternate explosion of gas on both sides of a piston. This engine, though comparatively antiquated, shows many of the modern principles; the most important one being the use of the non-compression system which we now find in some units.

William Barnett evolved the system of "naked flame" ignition in 1838, which he incorporated in the construction of his engine. This form of ignition has been extensively used for years in stationary power units, and has fairly recently been dispensed with for the less complex and more convenient types of ignition by electricity. In another respect also, we find Barnett's engine of interest, as it is one of the first gas engines which embodies the principles of high compression with which we are now so familiar. In mechanical structure, we also find this engine of especial interest, as it is about the first scavenging gas engine built. By the term "scavenging," we include all engines of the two-cycle type to which is affixed some suitable pumping or blowing device which is designed to render more positive the performance of its various functions. In the smaller units we may mention that it has not been found a commercial practicability to construct scavenging motors, but in high powered stationary engines of low revolutionary speeds, we find many cases where it has been adopted with marked success.

We find an instance of the first use of hot tube ignition in the year 1855, when A. V. Newton invented this system, which, until recently, was much used in foreign automobile practice.

Although up to this time much experimenting has been done, there was no instance where a practical commercial machine was ever built, and it is Lenoir who first initiated the gas engine in the commercial field. In 1860 Lenoir put on the market a horizontal gas engine, which was, in exact copy, a reciprocating, simple acting, steam engine, except for detailed changes in the admission and exhaust valves. An evidence of the commercial success of this engine is evinced by the fact that in 1865 over three hundred of his engines were operating throughout France. It is curious that this should be the case, for with a fuel consumption averaging from 2.5 to 3 cubic meters of gas per horse-power it could not compete with the poorest of our present units. However, for that time Lenoir's engine was considered highly economical.

During this period of comparative enlightenment among gas engineers, it is remarkable how erroneous were their ideas concerning the phenomena of the combustion of gases. Although Bunsen and Hirn were contemporaneous with this time, and fully understood and demonstrated the action of combustion in gases, yet we find cases where stratification of the gases in a cylinder was attempted by the injection of steam. The reason we learn for this experiment was the fallacious idea that by lengthening the duration of explosion a consequent gain in economy would be effected. This theory is in direct opposition to the now established fact that the greater number of heat units is derived during the actual expansion of the gases.

In 1876 Otto established his revolutionary change in the cycle of the gas engine. As previously mentioned, this cycle had already been considered from a theoretical standpoint by De Rochas. The economy of this new type was marked, for in the earliest four-cycle motors a fuel consumption was recorded of only 24-30 cubic feet per horse-power-hour. With this apparent advantage of economy, coupled with great reliability, Otto's engine soon ousted all other competitors from the field, and rapidly became the universally adopted type.

Some idea of the popularity of the Otto engine may be gleaned from the fact that since its manufacturing company was incorporated (1880), the firm has produced 25,000 separate units representing over 100,000 horse-power (to 1905).

Having considered, in outline, the growth of the low speed, internal combustion engine, we may now turn to the more recent evolution of the high speed motor.

It is the French and Germans whose mechanical genius has done much to perfect the modern motor, which has proven so highly successful in the propulsion

of many types of vehicles. And it is wholly to Gottlieb Daimler that the honor of its invention belongs.

This German engineer has well earned the appellation of "Father of the Automobile" for he was the first pioneer to successfully solve the problem of the self propulsion of vehicles. In 1886, Daimler, who was the manager of the "Otto Engine Works," at Deutz, Germany, built a simple form of air-cooled motor which he at first experimented with on a bicycle. Three years later he developed, from this experiment, a motor which proved so efficient that Messrs. Panhard & Levassor of Paris bought the necessary rights to it, and laid the foundation of a corporation which now leads the world in this particular phase of motor construction.

With the tremendous impetus thus given to the industry by Daimler a rapid development followed. Peugeot Freres and many other companies were organized, and gas engine manufacture soon took place on a far larger scale than heretofore.

To trace the metamorphosis of the high speed motor, it will be necessary to consider the history of the automobile, for it is in the usage of vehicle propulsion that this motor has been found most adaptable.

One of the earliest severe tests that is recorded in the history of automobiling, to ascertain the existing deficiencies in automobile engines, was the race which took place in France in the latter part of 1894. The competing machines were two 3.5 horse-power Panhard cars, which were respectively driven by Messrs. Panhard and Peugeot, both ardent enthusiasts in the sport. The following year a second race ensued in which M. Levassor, driving a Panhard, covered the distance of 730 miles at the then remarkable average rate of 15 miles an hour. But six years from that date the same course was covered at the average speed of 50 miles per hour, which demonstrated forcibly the phenomenal strides the industry had taken.

In the passing of the Locomotive Act in England, during the year of 1896, a great step was taken in the promotion of automobiling as a sport. Previous to this time, the public highways throughout the island had been closed to all self-propelled vehicles, or in legal phraseology, "light locomotives," so that automobile manufacture was practically non-existent. Following the acceptation of this bill in Parliament, there came a number of foreign built motor cars into England, which soon became so popular that in 1897 the Automobile Club of Great Britain and Ireland was formed.

Meanwhile, in America, the gas motor for vehicles had been developing on somewhat different lines.

In 1878 is recorded the first instance of experimenting in the application of the gas engine for motive power. In this year a Mr. Fawcett of Pittsburgh built an omnibus which was propelled by a Brayton motor. Brayton, though successful in his theoretical experimentation, never succeeded in producing a machine of any practical serviceability, and Fawcett's attempt was relegated to a long list of similar failures.

Following Fawcett's enterprise came C. E. Duryea's construction of a gasoline runabout, which was not completed until 1892. This vehicle was found to be very underpowered, but in 1894 the Duryea brothers adopted a four-cycle type of motor, which proved so efficient that a year later it was entered in the Chicago *Times-Herald* race, where its performance was exceptionally good. Stimulated by this success, in 1896 Duryea organized a company, which built the first thirteen automobiles manufactured in the United States.

Many other men were at the same time endeavoring to overcome the various constructional, and difficulties of design which the manufacture of the automobile engine involved. Mr. Elwood Haynes started his experimenting as early as 1888, but it was not until 1898 that the Haynes Apperson Company was incorporated.

Alexander Winton was also one of the early believers in the ultimate popularity of the gas engine, and in 1896 he constructed his first automobile for the market.

The names of Mr. R. E. Olds, Mr. H. Ford, and numerous others are also intimately coupled with the early growth of the art.

Though much work was done by our American engineers to perfect the automobile engine, it was on altogether different lines from foreign practice. It was generally believed among our pioneer engineers that the horizontal engine was the better type for the motive power in vehicles, but long years of constant experimenting and actual service has proven that the foreign idea of the vertical engine is by far the most preferable generally for automobile usage.

Concrete figures can illustrate more vividly than words the stupendous growth of a but lately infantile industry. The manufacture of automobiles in the United States in 1898 produced as a sum total but fifty machines, a production amounting to about $75,000. In 1913 the value of commercial and pleasure vehicles produced in this country conservatively figures over $670,000,000, and many consider the business as still in the development stage.

Ideal Form for Fast Airships

RESEARCHES made upon the shapes of fish which travel at fast or slow speeds in the water led two French scientists to consider that the usual shapes of airships have no proper basis for their design, and that for a high-speed airship the ideal shape should have somewhat the form of a shark. Moreover, to sail properly in the air, the balloon should be neither all-rigid nor all-flexible, but should have a combination of the two, that is, a rigid fore end and a flexible rear part.

Airships now in use can be placed in two classes; first, the Zeppelin type, which is made up of a middle cylinder with two conical end caps; and second, the French or flexible type having an elongated ovoid form, with the large end in front. The German airship has a shape which appears to correspond to no idea of adaptation, and its conception is the result of a special idea formed by the designer. On the contrary, the ovoid shape copies that of numerous fish. The two Paris scientists, Profs. Magnan and La Riboisière, now show that this shape with large end in front is the worst form of fish, and, in fact, the slow-speed fish all have the large diameter of the body near the front. Their body is likened to an ovoid made up of a cone having a spherical cap in front.

Observations upon fish make it clear that in the shapes of body where the large diameter lies nearer the rear, this characterizes faster speed fish, and speed follows this displacement toward the rear. Thus the very rapid fish, such as the shark, trout and the like, have the large part lying near the middle of the body and not in front. Again, they notice that rapid fish have not the same general shape of body as the others. They define the body of the rapid fish as made up of a rear cone pointing backward for the end of the fish, a front spherical cap for the head, and a middle or joining part, which is a truncated cone with the large base in the rear; that is, front rounded end, conical part expanding toward the middle, then a diminishing conical part toward the rear. Fish are adapted to the aqueous medium, and their shape results from pressures produced by the water on the body. It is the resistance which the water opposes to their progress that, so to speak, "models" the body of the fish. This is evidenced by the fact that mammifers, such as the whale, who left terrestrial for aquatic life, also have their bodies changed in shape, and in fact formed, as we have seen, so as to resemble the fish in shape. Since the form of the fish is the result of pressures due to the resistance of the water on a certain plastic body which moves at a given speed, we can affirm that the form of any given specimen of fish is that which corresponds to a shape having least resistance.

Rapid fish like the shark have, therefore, a special form, with large diameter near the middle of the body, because this form corresponds to that in which the effects of modeling by the water cease to manifest themselves. Basing their theories on the above conclusions, obtained from actual observation of fish, the authors design a form of balloon body to copy the rapid fish, such as the shark. One interesting point is that the fore end is rigid, and this part is made as a kind of penetrating cone, the rest of the balloon being flexible. This is not only designed after natural conditions, but follows from experiments in which they observed the effect of a bag filled with a thick liquid and placed in the water. It cannot move rapidly through the water unless it has a rigid fore-end, either conic or spherical.

The nacelle of the airship is placed underneath and as close up against the body of the balloon as possible, so as to lessen the resistance to the forward movement and to keep the whole airship close to the ideal shape. At the back of the balloon body is a pair of rudders arranged somewhat like a fish's tail. The dimensions of the proposed airship are: Volume, 200,000 cubic feet; length, 220 feet; maximum diameter, 52 feet; distance of point of maximum from the front end, 120 feet. Width at the maximum is somewhat smaller than the height, or 46 feet, so that the section is not exactly circular, this idea being also copied from the fish. Length of the rigid front cone, 46 feet.

The Spectrum Extended in Extreme Ultra-violet

THE researches of Schumann enabled him to extend the spectrum to about λ1250, and subsequently Mr. T. Lyman continued it to λ1030 by the use of a concave grating. Now Mr. Lyman has succeeded in photographing the spectrum of hydrogen to λ905. It is characteristic of the region investigated by Schumann between λ1850 and λ1250 that, while hydrogen yields a rich secondary spectrum, with the possible exception of one line no radiation has been discovered belonging to the primary spectrum. On the other hand, in the new region between the limit set by fluorite and λ905, a disruptive discharge in hydrogen produces a primary spectrum of great interest made up of perhaps a dozen lines. These lines are always accompanied in pure hydrogen by members of the secondary spectrum, but they may be obtained alone if helium containing a trace of hydrogen is employed. Results obtained from vacuum tubes when a strong disruptive discharge is used must always be interpreted with caution, since the material torn from the tube itself sometimes furnishes impurities. In the present case, it will be some time before the effect of such impurities can be estimated. However, it may be stated with some degree of certainty that the diffuse series predicted in this region by Ritz has been discovered. The first member at λ1216 is found to be greatly intensified by the disruptive discharge, and the next line at λ1026 appears also, though very faintly. This diffuse series bears a simple relation to Balmer's formula. Following the same kind of argument, a sharp series corresponding to the Pickering series might be expected. The new region appears to yield two lines belonging to such a relation at the positions demanded by calculation.

Drying Grain by Electricity

AT some mills grain is being dried by electricity. The heating devices are installed in the casing inclosing the spiral screw that conveys the grain from the storage bins to the stones, and the grain is thus thoroughly dried immediately before it is ground. This drying is reported to make the grinding easier and to also insure a better and more uniform quality of the product of the mill.

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Table of Contents

PAGE

Electric Furnaces for Heating Steel.—I.—4 illustrations.—By Alcan Hirsch 3338
The Arrow Rock Dam.—3 illustrations.—By Charles J. Lisle 3340
Coffee Growing in Paraguay 3340
Handling Rails Cheaply 3340
Calorizing.—8 illustrations.—By H. B. C. Allison and L. A. Hawkins 3341
The Resistance of a Ship's Motion.—7 illustrations 3342
What an Incompetent Workman Costs 3343
Producer Gas from Low Grade Fuels.—14 illustrations . . . 3344
Belgium's War Dogs 3346
Red as a Danger Indication.—By William Churchill 3346
Ben Franklin Vindicated 3347
The New York Fire Alarm System.—3 illustrations.—By Putnam A. Bates 3348
Stereoscopic Drawing.—10 illustrations.—By Charles E. Benham 3350
An Historical Sketch of the Gas Engine.—By John Hays Hammond, Jr. 3351
Ideal Form for Fast Airships 3352
The Spectrum Extended in the Extreme Ultra-violet 3352
Drying Grain by Electricity 3352

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PAGE

338

340
340
340

341
342
343
344
346
346
347

348

350

351
352
352
352